Cold Welding Polymers

Polymeric materials are used to solve many diverse repair and mechanical engineering problems onboard. They are particularly useful when hot work like welding and brazing cannot be performed. The applications can vary from structural bonding to rebuilding corroded/eroded metal prior to application of protective coating through to emergency and permanent repair of holes and cracks.

Two parts Epoxies (base and activator) have been known since the early 1950s as structural adhesives for metal due to their high adhesion, strength, high load bearing and cold bonding capacities. Nowadays they are used universally as a replacement for traditional mechanical engineering joining methods.

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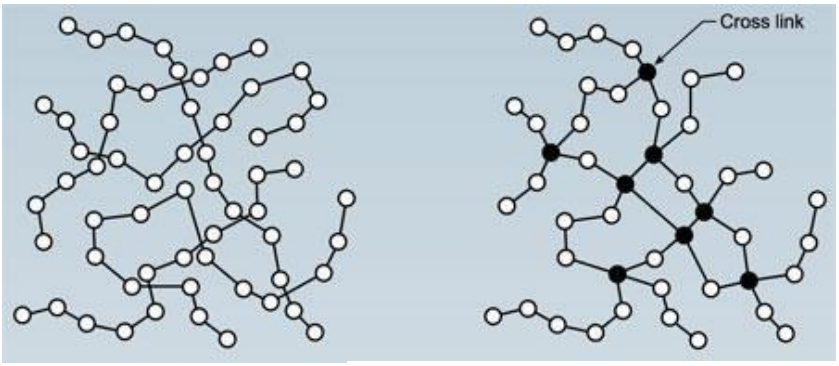
Notification regarding the Product comparison list in this paper:

Effort has been made to check the accuracy of the product comparison lists. However, products from manufactures can vary quiet considerably. Therefore, if your repair is critical, contact the selected product manufacturer for detailed information.

INTRODUCTION

A polymer is a molecule that is made by linking many small units (monomers) together to form a large molecule. The polymer can be made of a single species (homopolymers) or of several different monomers (copolymers). Polymers occur naturally, (biopolymers) but are also made synthetically in large amounts. The term polymerization describes the chemical reactions that produce polymers by repeated combination of monomers to make long or large molecules. The different types of reaction are numerous and several distinctly different ways of categorizing the reactions are used.

It is important to understand the difference between Thermoplastic and Thermosetting polymers.



Thermoplastic Thermosetting

Thermosetting and thermoplastics are two different types of polymers and they are mostly separated based on their molecular bond and reaction to heat.

Thermoplastics have secondary bonds between molecular chains. They have low melting points due to which it can further be remoulded or recycled easily.

Thermosetting plastics have primary bonds between molecular chains and held together by strong cross-links. They have a very rigid structure and have high tensile strength. They can withstand high temperatures and once hardened these cannot be reformed or recycled even with the application of heat. **Cold repair polymers are based on Thermosetting polymers.**

What triggers the thermosetting compounds are the chemical reactions between Base (Resin) and Activator (Hardener) producing an extensive interlocking network. The process is exothermic (heat is given off). They will normally be polyester, polyurethane and epoxy materials and the Base/Resin will in most cases have a filler material added.

The work site temperature must be above 5ºC (40ºF) in order for the chemical reaction to take place. The higher the temperature the faster the products will cure.

WHERE TO USE, AND WHERE NOT TO USE

Where Cold Repair polymers should be used:

If no energy source in the form of electricity for arc welding or oxy-acetylene gas for gas welding or brazing are available Cold Repair Compounds represent the alternative. The energy is built into the product and is released when base and activator is mixed together. It is a fast solution because the curing time for some of the products is down to a few minutes. Uncomplicated in use and no rigging up time makes it perfect for emergency repairs.

Where Hot work is not permitted

Cold repair systems are a cold curing processes. There is no risk of heat or sparks causing ignition. Maximum temperature during polymerisation can reach 70ºC (158ºF). Base materials chemistry is normally of no concern because the bonding is mostly mechanical and not chemical.

Where base material is not weldable

Certain materials are simply not weldable because of chemistry or because the material is so corroded that there is nothing to weld on. Sometime welding method/ equipment/ consumable or operator knowledge is not available.

Where distortion is Unacceptable

Welding causes expansion and contraction resulting in distortion. If this is unacceptable, cold welding polymer can be the solution.

Where there is restricted space

Polymer products can if necessary be injected trough small openings and holes.

Where specific properties are required

In many cases, polymer materials have better wear properties than weld overlays. Specifically, with regards to wear and tear in fluid flow environments. Large surfaces that are worn are also much faster overlaid with polymer materials than with weld bead overlays.

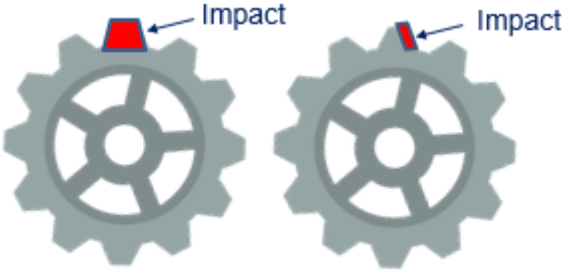
Where you need non-metal repairs

Rubber, plastic and composite materials cannot be repaired by traditional welding methods. Polymer will very often represent the perfect solution for this type of materials

When Cold Repair compounds should not be used:

At low temperatures: When the ambient temperature is below 5ºC (40ºF) there will be no curing/ solidification. Polymerisation will not start if the temperature is below 0ºC (32ºF).

Unsupported side impact



Most polymer products will fail if unsupported side impact applications are at play.

Unsupported Supported

High temperatures

Polymers are mostly made from organic materials. At service temperatures above 120ºC (248ºF) they will start to carbonise and fail in service. There are high temperature polymers that can take up to 180ºC (356ºF) For elastomers (Rubber grade materials) the limit is around 90ºC (194ºF) There are in-organic polymers available, but they might have other limitations.

INTERNATIONAL STANDARDS

Polymer repairs are governed by the ISO 24817 and ASME PCC-2 International Standards whitch classify all intended repairs based on temperature/ pressure/ content service usage.

Also, by lifetime of up to 2 years, where the repair is required to survive until next shutdown, after which equipment shall be replaced.

Long lifetimes up to 20 years where the repair is required to reinstate equipment to its original design lifetime or to extend its life is outlined.

For further information on ISO 24817 and ASME PCC-2 go to page 53.

APPROVALS OF THERMOSETTING REPAIR PRODUCTS BY CLASSIFICATION SOCIETIES

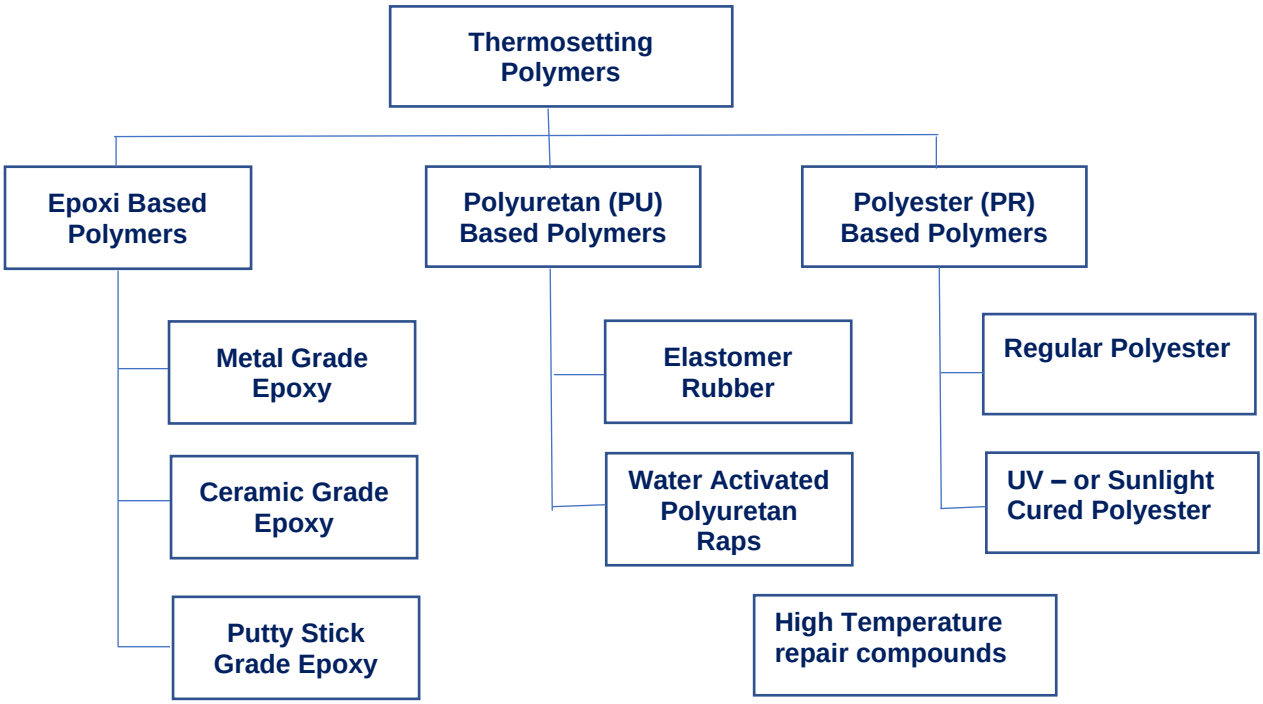
Some of the thermosetting compound manufacturers have their products type approved by classification societies. The society will state that the specific manufacturers product has met the requirements for two component epoxy-based repair and maintenance products. The approvals will list the products approved by name, give a description, rating, intended service and validity. The societies will in some cases make remarks that the product is for temporarily use only. They can also inform limitations of use towards ships parts under pressure, specific temperature and dynamic cyclic loading.

TERMINOLOGY

In the literature there are a number of expressions in use all depending on polymer system, manufacturer and country of origin.

Base: is also referred to as Resin
Activator: also referred to a Hardener. Also curing agent, catalyst and Initiator is sometimes used depending on type of thermosetting system.
Addition: bonding between the polymer product and the base material (substrate).
Compound: also referred to as Paste or Putty. Also referred to as non-sag and trowel-able.
Filler: metal or ceramic type of powders added to the base part.
Fluid: also referred to as Brush-able and Liquide polymers.
Gelled: product in semi-liquid state and set to become more solid.
Pot Life: time available depending on temperature before product start solidifying.
Curing Time: The time depending on temperature it will take the mix of base and activator to cure. Curing time can be given as:
Initial setting: when light load can be applied.
Machining: when product can be machined or grinded.
Full Mechanical Strength: when product have reached its maximum strength. This can for some products take days.
Full Chemical Resistance: when product have reached the strength to withstand the chemical(s) it is intended for.

PRACTICAL THERMOSETTING POLYMER PRODUCTS OVERVIEW



EPOXY BASED POLYMERS (METAL AND CERAMIC GRADE EPOXY)

Epoxy Based Polymers (two parts) are the most common type polymer repair products.

Base

Activator

Metal Grade Epoxy have metal fillers added. This can be iron mixed with phosphorus which are non-magnetic, and alloys of iron with silicon, which are ferromagnetic. They are used to impart metallic properties to polymer such as appearance and thermal conductivity without compromising corrosion resistance.

Product comparison list: **Metal Grade Epoxy**

Product Type	**Unique polymer system**	**Belzona**	**3M Scotchkote ****	**Devcon (ITW)**	**Chesterton ARC**	**Loctite**	**Enecon**	**Thortex (3M)****	**Wencon**	**Wilhelmsen Ships Service**	**Eli-Chem**
Paste grade	UPS 105 EG	1111 Super metal	Metal Repair EG 503	Plastic Steel / 10765/ 10271/ 10115	ARC 10	3478/ 3471	Metal Clad Duralloy	Metal-Tech EG	Cream	Metalgrade Rebuild	FR 912
Fluid grade	UPS 110 FG	1821 Fluid Metal	Metal Surfacer FG 502	Plasti steel liquid/ 10211/ 215/ 217	ARC 12	3472		Metal-Tech FG	Coating		FR 982
Paste Grade Long pot life*	UPS 115 XL	1121 Super XL Metal	Epoxy Metal Repair XG 509					Metal-Tech XG	Hi-Temp		
Fluid grade Fast curing	UPS 120 XFF	5831									
Paste grade Fast curing	UPS 125 XFP	1161/ 5831/ 1221	Metal Repair RG 501	SF	ARC 5		Metal Clad Speed Alloy. Speed Alloy QS	Metal-Tech RG	Rapid	Metalgrade Express	FR 913
Stick grade	UPS 19060 SG	1291	Epoxy Metal Repair SG 527	Magic-Bond	ARC 5ES	3463		Metal-Tech SG	Putty	Metalgrade Ready Stick	FR 308
Stic grade Under Water	UPS 19060 SGUW				ARC 5ES						
Underwater	UPS 19065 RG	1212	Urethane Metal Repair RG 501						UW Cream UW Coating	Aquagrade Rebuild	FR 986

*When additional working time is essensial for applying product.

Product comparison list: **Metal Grade Epoxy** (Continue)

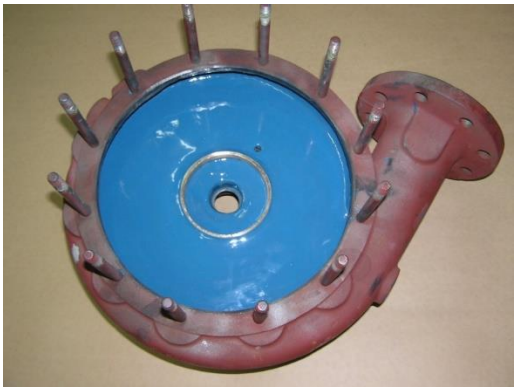
Product Type	**Velodur Durmetal**	**Mega Metal**	**Multi Metall**	**Castolin Eutectic**	**Unirep**	**Huntsman**
Paste grade	Standard A+B	Mega steel	MM-Metal SS- Steel Pasty	MeCaFix120	Unirep 3	Araldite 1258 A/B
Fluid grade			MM-Metal SS- Steel Liquid			
Paste Grade Long pot life*					Unirep 9	
Fluid grade Fast curing						
Paste grade Fast curing	Super-Rapid CA/HD	Mega Quick	MM-Metal SQ	MeCaFix100 Express	Unirep 1	Fastweld 10 A/B Epoxy adhesive
Stick grade		Mega Stick			Unirep 27	
Stic grade Under Water		Aqua Stick				Araldite Repair Aqua
Underwater			MM-Metal UW			

*When additional working time is essensial for applying product.Product viscosity: Paste grade products, by some manufacturers referred to as a putty or compound, will have to be mixed and applied by the use of a spatula.

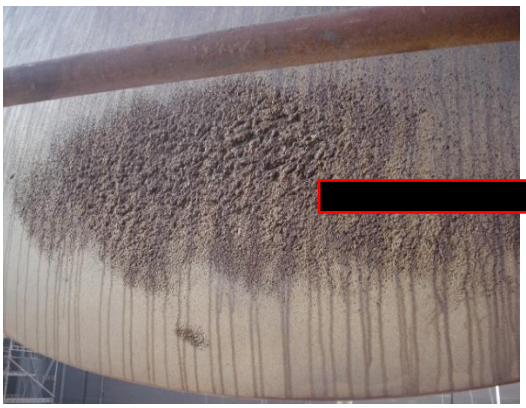
**3M Scotchkote/ Thortex:
E.Wood, manufacturing the Thortex/Copon brand was purchased by 3M in 2007/2008 thereby adding a polymer repair range to their already exsisting product range.

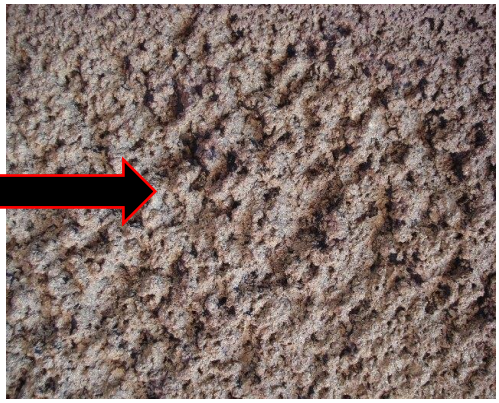
Fluid grade products can be poured or brushed on to the substrate (base material).
Stick grade product is like a putty and can be kneaded by hand in order to mix and applied.

Ceramic Grade Epoxy can be enhanced further with the addition several grades of high-quality silicon carbide fillers. They are often used in fluid flow environments (pump housings, impellers, valves and piping). Heavy damage will be rebuilt using a compound type ceramic grade followed by one or two layers of a fluid brush grade ceramic.

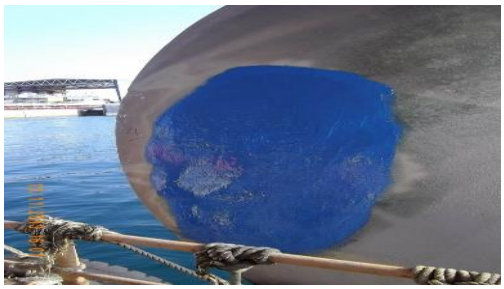


Pump housings and impellers are typical repair applications for ceramic grade epoxy.





Ships propeller blade with deep sponge like wear caused by cavitation.



The deep cavitations are first rebuilt using a ceramic compound followed by two layers of fluid grade ceramic .

Product comparison list**: Ceramic Grade Epoxy**

Product Type	**Unique polymer system**	**Belzona**	**3M Scotchkote**	**Devcon (ITW)**	**Chesterton ARC**	**Loctite**	**Enecon**	**Thortex (3M)**	**Wilhelmsen Ships Service**	**Eli-Chem**
Ceramic Repair Paste	UPS 200 EG	1311 Ceramic R Metal	Epoxy Ceramic Rebuild EG 513	WR-2 Wear Resitant Putty	ARC 858	7218	Metal Clad Ceramalloy CP+AC	Cerami-Tech EG	Ceramigrade Rebuild	FR 1010 LV
Fluid Grade Ceramic	UPS 205 FG	1321 Ceramic S Metal	Epoxy Ceramic Surfacer FG 512	WR Brushable Ceramic 11762	ARC 855	7227/ 7228	Metal Clad Ceramalloy CL+AC	Cerami-Tech FG	Ceramigrade Liner	FR 1011
Fluid Grade Low friction efficiency	UPS 210 CR	1341 Supermetal Glide	Epoxy Ceramic Surfacer CR 511	WR Brushable Ceramic 11762	ARC S2/ 855/ S3	7226	Metal Clad Ceramalloy CL+	Cerami-Tech CR		
Fluid Grade High Temperature	UPS 225 HT	1391	Epoxy HT Lining HTX 517				Metal Clad Ceramalloy HTL	Ceram-Tech HTX		FR 1008 (Paste)
Fluid Grade High Acid	UPS 226 HAC	1392								
Bruch Grade Toughened	UPS 236 TUC		Urethane Ceramic Lining FG 514				Flexiclad Dura Tough DL	Cerami-Flex FG		
Paste grade Heavy Duty (for sliding abrasion)	UPS 519 HD	1812 Ceramic/1811	Epoxy Ceramic HD Surfacer HG 519		ARC 890/ 897		Metal Clad Ceramalloy CBX	Cerami-Tech HG	Ceramigrade Abrashield	
Fluid grade Underwater	UPS 250 UWC	ST Barrier								

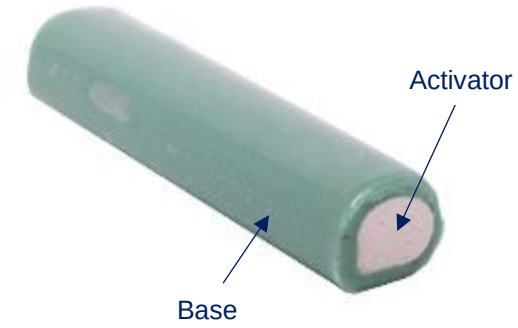
Product comparison list**: Ceramic Grade Epoxy** (Contiue)

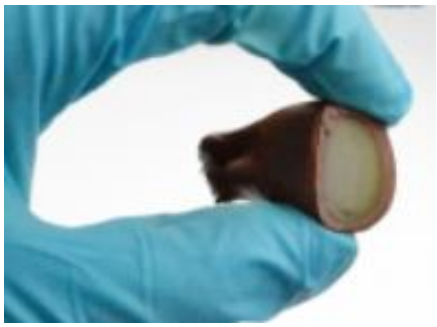
Product Type	**Mega Metal**	**Multi Metall**	**Castolin Eutectic**	**Unirep**	**Huntsman**
Ceramic Repair Paste	Mega-CS	Ceramium 601	MeCaWear A5	Unirep 13	Araldite XMH 8510
Fluid Grade Ceramic	Mega-Tech Ceramic Paint Micro-Bead Mega C	Ceramium 602	MeCaWear 300	Unirep 12	Araldite XMH 8518
Fluid Grade Low friction efficiency			MeCaWear 350		
Fluid Grade High Temperature			MeCaWear A5 HT		
Fluid Grade High Acid			MeCaCorr 750		
Bruch Grade Toughened			MeCaWear 400		
Paste grade Heavy Duty (for sliding abrasion)				Unirep 20	Araldite XMH 8507

Where fillers are concerned, both Metal and Ceramic grades, manual mixing is preferred method having base and activators in separate tins. Low filler contents for pouring and brushing. Higher filler content compounds require use of a spatula. The viscosity of the product (compound or fluid) depends on application. Also take work position into consideration. If the product is to be applied in the vertical position it might be important that it is non-sag/ trowelable compound. Inorganic pigmentation can be added to both base and activator, each a different colour as a visual means of verifying complete mixing. Electrically conductive fillers such as powdered copper, silver and graphite, or thermally conductive metal alloy fillers are typically added to provide polymeric products with conductance properties.

PUTTY STICK GRADE EPOXY

Putty Stick Grade Epoxy is mostly used for covering small gaps, filling holes and repairing cracks. Each type is made from epoxy resin with a different kind of filler. They can all be kneaded by hand and set hard. The exact degree of hardness varies, but none remain soft or flexible once they're fully set. Aluminium flake and powdered steel and titanium are among the common metals that find particular use in two-part epoxy repair putty sticks. Two-part repair compounds and putties are relatively easy to mix and apply without the need for special tools. They are based on volume mix ratios. The putty stick variants have their ingredients premeasured and amalgamated into a single piece with a filler base component on the outside protecting activator on the inside.





Epoxy repair putty sticks are available with Mineral fillers, Aluminium fillers, Ceramic fillers, Copper fillers, Stainless Steel fillers and Titanium fillers. There are also underwater-setting epoxy repair putty sticks for repairing, patching and rebuilding equipment in chronically wet environments – even underwater.

The putty sticks are often part of the Water Activated Polyurethane raps kits for pipes. The stick is used for sealing the actual hole and the water activated rap is further strengthening the repair when the polyurethane bandage is wrapped around the pipe.

Product comparison list for putty stick grade epoxy: Look under comparison list for Metal Grade Epoxy.

POLYURETHANE BASED POLYMERS (ELASTOMERS AND WATER ACTIVATED POLYURETHANE WRAPS)

Polyurethane Based Polymers (PU), are recognised for their toughness and flexibility at low temperatures.

Elastomers (synthetic rubber) is a polyurethane based product used for rubber and metal repair. They can be mixed and deposited using a cartridge gun* or manual mixing having base and activators in separate tins. There is also a system where base and activator is delivered in a twin plastic pouch. When a divider in the pouch is removed, base and activator flow together and are further mixed together by kneading and squashing the pouch. When a corner in the pouch is cut the mixed product can be squeezed out.

Elastomers are available in different hardness. Hardness Shore A 60 is like soft rubber. Hardness Shore A 90 is like the hard rubber used in car tires. Make sure to select a Shore Hardness that suits the application. Elastomers are available as compound type and fluid grade material. Some suppliers/ manufacturers recommend to use a primer on the prepared rubber surface before applying the actual product. For all application on rubber surfaces it is of the outermost importance that the surface is roughened.

*Polymers and adhesives intended for automated mixing and dispensing, especially by the two-part cartridge guns with static mixer nozzles, are generally formulated without filler materials.

Product comparison list**: Elastomer/ Rubber**

Product Type	**Unique polymer system**	**Belzona**	**3M Scotchkote**	**Devcon (ITW)**	**Wilhelmsen Ships Service**	**Loctite**	**Enecon**	**Thortex (3M)**	**Eli-Chem**
Paste Grade 60 Durometer	UPS 305 EG Paste grade	2211 MP Build Elastomer	Urethane Elastomer 60 RG 537	15821/ 046 Flexane GP	Rubbergrade 6 Rebuild		Flexi Clad PC	Flexi-Tech 60 RG	Eli-Flex Paste
Fluid Grade 60 Durometer Fast curing	UPS 310 RG Rapid grade	2311 SR Elastomer 2221	Urethane Elastomer 60 FG 534	15050/ 810/ 812 Flexane 60L	Rubbergrade 6 Remould		Flexi Clad ER	Flexi-Tech 60 FG	Eli-Flex Liquid
Fluid Grade 80 Durometer	UPS 315 FG Fluide grade	2131	Urethane Elastomer 80 FG 532	15800/ 810/ 262				Flexi-Tech 80 FG	
Paste Grade 80 Durometer	UPS 320 EG Paste grade	2111	Urethane Elastomer 80 EG 531					Flexi-Tech 80 EG	
Paste Grade Grade 80 Durometer Extra fast curing	UPS 80 XRG Faste grade		80 XRG 539			PC 7350* (Grade 95 Durometer)			

*Cartridges mixing system

Product comparison list**: Elastomer/ Rubber** (Continue)

Product Type	**Mega Metal**		**Multi Metall**
Paste Grade 60 Durometer			
Fluid Grade 60 Durometer			MM-Elastomer 958
Fluid Grade 80 Durometer	Wear-Flex Quick Mix 3500		MM-Elastomer 956
Paste Grade 80 Durometer	Wear-Flex Quick Mix 2500		MM-Elastomer 951
Paste Grade Grade 80 Durometer Extra fast curing			

*Cartridges mixing system

Water Activated Polyurethane Raps is also in the polyurethane groups of polymers. This type of products consists of a bandage wrap pre impregnated at the manufacture to ensure that optimal fibre to resin ratio is maintained. The product is supplied in moisture proof bags. When opened at work site and exposed to moisture the curing process will start.

After being removed from the pouch the pre impregnated bandage is immersed in water and wrapped around the pipe. It is often used together with the epoxy repair putty stick.

Product comparison list**: Water Activated Polyuretan raps**

Product Type	**Unique polymer system**	**Belzona**	**3M Scotchkote**	**Indu-Mar**	**Marine & Industrial Marketing**	**Loctite**	**Wilhelmsen Ships Service**	**Thortex (3M)**	**Wencon**	**Eli-Chem**	**Unirep**
Emergency Pipe repair bandage	UPS 19601/ 4/ 5 PR	9631	Urethane Pipe Repair PR 504	Stop-It	Rapp-It	5070 Pipe repair kit	Leak-Stop	Metal-Tech PR	Pipe tape	Eli-Wrap	Unirep 80

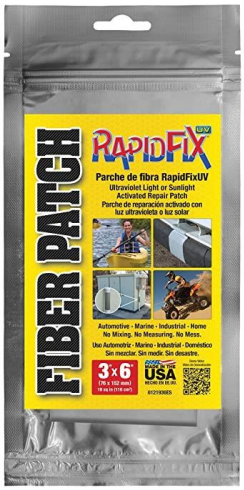
Product comparison list**: Water Activated Polyuretan raps** (Continue)

Product Type	**Mege Metal**	**Unirep**	Weicon
Emergency Pipe repair bandage	Quick Wrap	Unirep 80	Pipe repair kit

POLYESTER, REGULAR AND UV / SUNLIGHT CURED POLYESTER

Regular Polyester resins are unsaturated synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Cobalt salts are usually used as an activator. Polyester resins reinforced with fiberglass is referred to as fiberglass reinforced plastic (FRP). Most polyester repair kits on the market for repair of fiberglass reinforced plastic contains the polyester base, activator and a fiberglass mat.

UV – or Sunlight Cured Polyester
The only difference between UV-Sunlight cured and regular polyester resin is that UV-Sunlight cures "within minutes," when exposed to Ultra Violet light produced from the sun or artificial light source (tanning bulbs) instead of having to add activator.
The UV (Ultraviolet curing) system have long been used by the dentists. It's that blue light called the dental curing light. It is a gun like machine with a light emitting source attached to its head.
For repair purposes in the mechanical industry the UV - or sunlight activated, self-adhesive repair patch is a fibreglass reinforced polyester. Activated by ultraviolet light (both natural sunlight and UV lamp). It cures by direct sunlight or under the support of an UVA-lamp with wave length of 320 -400 nm. It will bond to most surfaces except Polypropylene (PP). The primary limitation of light-induced curing system is the limited light penetration depth which will depend on the wavelength and spectral distribution and usually does not exceed a few millimetres.



The self-adhesive repair patch is a convenient way to perform a repair but light cured polyester is also available as a water clear liquid in a container. NB If one adds a thick, heavy coloured laminate bandage that do not let light pass through one will need to add a small amount of activator resin that will eventually harden any areas underneath any areas blocked by UV light.
There is always a downside: Polyester resin has a 6-month shelf life.

SPECIAL PRODUCTS (HIGH TEMPERATURE, POLYMER KITS, EMERGENCY KITS)

Product comparison list**: High Temperature (Up to 1300 ºC/ 2400ºF)**

Product Type	Wencon	Wilhelmsen Ships Service
One component	Exhaust repair kit	Metalgrade Hi Temp

Product comparison list**: Polymer Repair Kits**

Product Type	**Unique polymer system**	**Weicon**	**Enecon**	**Durmetal**	**Wencon**	**Wilhelmsen Ships Service**
First aid Emergency kits	UPS 13000 C Kit Engineering A UPS 2006LPRK Large Pipe Repair Kit UPS 19500/3/4/5 SPRK Small Pipe Repair Kit UPS 771/2/3/4 Marine Kit	Marine Emergency Repair Kit 1, 2, 3	Emergency Leak Repair Kit. Emergency Mechanic's Repair Kit.	Durmetal Repair Kit	Kit 1 Kit 2 Kit 3 Kit 4	Kit-A

Ships Emergency repair Kits

This is not the same as polymer repair kits. Ships Emergency repair Kits can contain polymer repair products, but also mechanical items like clamps, plugs, patches and fasteners in order to assist in a variety of emergency situations.

Product Type	**Indumar**	**Wheel House**	**AbsorbentsOnline**
Emergency repair kits	First Response Leak Repair Kit. Emergency Leak Control Kits D & AE. Pipe Leak Control Kits C2 & C3. Pipe Plugger Kit C-1. Roll over Kit.	SeaKits Damage Control Kit Standard. SeaKits Damage Control Kit Large.	Pipe Leak Kits Tank Leak Kits Drum Leak Kits

WHAT TO CHECK

There are a large number of manufacturers on the market offering Thermosetting polymer repair product solutions. Make sure to always check:

- Shelf Life. Most polymers have a shelf life of approx.2 years. Many products even less than that. Keep in mind that products can have been stored at manufacturer/ship chandler for a long time before being delivered onboard. Therefore, check manufacturing date on arrival.

- Storing conditions: The proper storage of thermoset materials is key to maintaining their processability. Shelf life is affected by ambient temperature. The changes in the material do NOT occur suddenly. They occur gradually over a period of time. Thermoset materials should always be stored in their unopened original containers until ready for use. Epoxy should be stored in a cool, dry place when not used for a long period of time. A shelf life of 3 years from date of manufacture can be expected when stored at room temperature 22 ºC (77ºF) in their original containers. Polyurethanes: Store in dry conditions between 10°C (50ºF) and 40°C (104ºF), away from sources of heat and naked flames. Protect from frost. When stored in original sealed containers, the minimum shelf life is two (2) years. If the original container is opened but all the material is not used, the container should be resealed to help prevent the gain or loss of moisture or the loss of volatiles.

- It is important to check the selected polymer products chemical resistance towards the application (chemical environmental conditions expected). Inquire with supplier for details towards the polymer's chemical resistance. NB. It will be necessary for supplier not only to be informed type of chemical, but also its concentration, flow velocity and temperature.

- Material Safety Data Sheet must always be provided.

- All materials and products that treat or come in contact with potable water (**drinking water)**, such as plumbing components should be approved for this purpose (NSF official listings).

- Is the product approved by a classification society? If so, is there limitation for use and are the approval up to date?

Composite repair

Polymer repair application on pipes including straights, elbows, tees, flanges, reducers, valve bodies, tanks and vessels often involve the use reinforcement bandages to strengthen the repair.
This is referred to as a composite or a laminate repair or fibre-reinforced polymer composites.

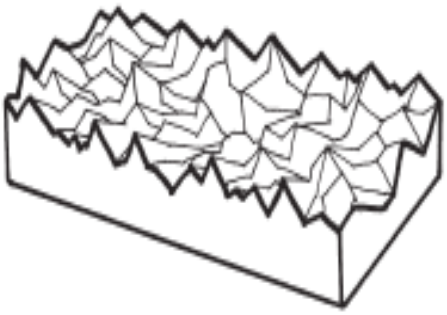
The reinforcement bandage/ tape consists of synthetic fibres and woven fabrics made from e-glass, carbon fibre and Kevlar fibre reinforcements. They are used in combination with epoxy, UPR, VE, MMA and PU resins which are applied either as composite wrap systems, pre impregnated wraps, or as adhesively bonded pre cured wrap systems.

GENERAL WORK PROCEDURE

Polymer compounds for repair onboard will in majority of cases be two component materials that cure, or harden, by chemical reaction between the base (resin) and activator (hardener) when they are combined.

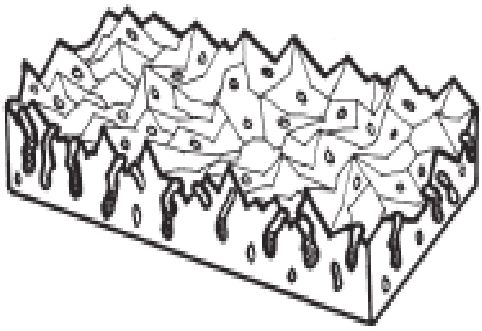
Do not apply product when relative humidity exceeds 85% nor when surface is less than 3 ºC above dew point.

How to prepare surfaces



Improve the bonding by roughening the surface

The bonding between the polymer compound and the base material is referred to as adhesion. It is not a chemical bonding like in welding. The bonding is partly mechanical (approx.80%) and partly chemical hydrogen bindings (approx.20%). It is therefore important to put a lot of attention into surface preparation. Oil, rust and other impurities represent a barrier that will prevent addition so important that surfaces are cleaned. Roughening of the surface also increases the surface area and gives a better key. Create if possible, a cross scoring pattern. Important that surface is roughened not polished.



Oil, seawater or other chemicals can over time have impregnated the part to be repaired. Casted parts have an open structure where liquids under pressure gradually can penetrate into the casting.

Critical repairs as pump house repairs should therefore be abrasive blasted to a minimum standard SA 2 ½. Profile 75-125 microns. The blasting medium should be angular grit. Castings might have been salt or chemically impregnated. If this is the case, they should be heated to 80ºC (176ºF) by hot air over night to sweat out the contamination. Remove the contamination using a cleaner, then re blast the surface.

To prevent sticking of polymer compound to a surface, coat the surface with a coating material such as Teflon, silicone or wax.

Preparing of Aluminium surfaces:
Oxidation on aluminium surfaces reduces epoxy adhesion. This oxidation film must be removed just before applying the polymer product. Aluminium will oxidise very fast. Therefore, have the polymer product ready mixed before final cleaning of the aluminium.
Remove oxidation by mechanical means such as grit-blasting or by chemical means such as acid etching.

Preparing of Rubber surfaces:
Rubber surfaces are particularly difficult to roughen. There are special tools for abrading of rubber. Abrade rubber surfaces using a rubber rasp or a grinder with a wire wheel to produce a good surface profile. (Oils and contaminants imbedded in the rubber surface are typically released in this process.) Remove all oil and grease from the rubber surface with a surface cleaner and an abrasive pad. Wipe the surface with a clean, lint-free cloth continuously until black residue is no longer picked up by the white cloth. If manufacturer recommend primer: Prime the surface as follows: Rubber to metal: Coat all metal surfaces (including stainless steel and aluminium) with primer. The primer will significantly improve adhesion of elastomer products to metal. Rubber to rubber: Coat all gum rubbers, neoprene, or cured urethanes with a thin coat of primer.

The Measuring:

For proper performance, polymer compounds must be mixed in specified ratios.

Always measure out Base and Activator quantity's accurately and in line with instruction on the tech/ date sheet. If a critical application, use mixing ratio per weight. Polymer compound should be mixed in small masses to prevent the material from curing too rapidly.

The Mixing:

This chemical reaction generates heat. It's important to keep the following principles in mind when doing the job:

•The larger the mass of polymer compound, the faster the cure.

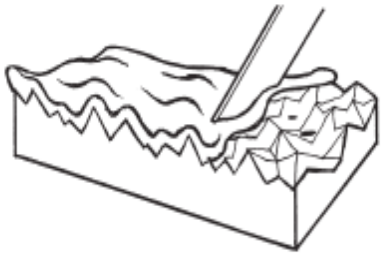
•The higher the ambient temperature, the faster the cure.

Mix Base and Activator until streak free. Any base or activator not mixed sufficiently will not solidify and weaken the final repair. Do the mixing on a clean flat plate spreading it out thinly. This will slow down the curing process. Make sure to familiarise yourself with the products pot life. This is the time you have available before product start solidifying. The pot life depends largely on the ambient temperature. The higher the temperature the shorter the pot life. Typical pot life for 500g of polymer compound at 24ºC (75ºF) is 45 minutes. Full mechanical strength is achieved overnight (16 hours). Specially formulated epoxies are available that offer fast cure time, extended cure time, wet surface/low temperature cure, high heat resistance and high tolerance to chemicals. When doing a polymer application, be sure to specify the polymer compound with the best performance characteristics for the job.

For fluid grade polymers: Transfer the contents of Base and Activator from the respective jars into a mixing container according to ratio indicated on the products tech sheet. The two components should be thoroughly mixed until completely streak free and a uniform colour is achieved, using a spatula. Most mixtures are initially fluid, but becomes thicker as it sets. Preferably transfer the mix from the first mixing container to a second container and continue mixing. This in order to ensure that that base and activator is completely mixed.

Applying:

Do not heap the product on. This will lead to bad bonding. A good bonding is secured by pressing a thin layer of product on to the surface, working it down in cracks and openings. After the bonding is secured, add more product and build up to required height.



Press first a thin layer of product onto the surface

Do not heap on the product

For fluid grade polymers: Using a brush the mixed material should be painted evenly onto the prepared area, working the material into any cracks and surface defect. When a second coat is required, this should be done as soon as the first coat has set (normally this will be within 4 hours).

Most polymer compounds will not cure properly at temperatures below 15ºC (59 ºF) unless the polymer compound, and if possible, the part to be repaired are heated to room temperature. To promote curing of polymer compound at low temperatures: The material should be mixed, applied to the repair area and warmed with a heat lamp or other heat source. Heat lamp should be placed about 0.5m from the polymer compound. Never expose the polymer compound to a direct flame.

The Finish

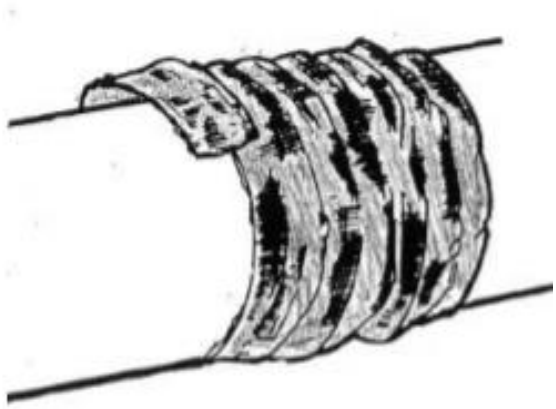
To obtain a smooth finish cover the uncured polymer compound with a sheet of polyethylene or waxed paper. Remove the sheet when the epoxy is fully cured. The surface can also be smoothed with a trowel moistened with water across the surface of the uncured material. Moisten the trowel with each stroke. Most polymer compounds will cure overnight (16 hours) at which time the material can be machined, drilled or painted. As previously described, the actual cure time for a particular polymer compound is determined by the size of the mass of polymer and the temperature. Under some conditions the compound will reach full cure in less than 16 hours. For example, most polymer compounds will be fully cured in only 4 hours when heat cured at 65ºC (149ºF).

PRACTICAL REPAIR WORK PROCEDURES ONBOARD

INDEX:

Holes in pipes and castings

One of the most common application for repair by polymer products are leaking pipes. There are 1000 of meters of pipes onboard and in some cases there is a need for emergency repairs in order to avoid closing down machinery



Measure up, mix and apply the polymer compound to the prepared pipe surface. Wrap the reinforcement bandage/ tape around the pipe making sure the tape is impregenated and ecapsulated into the polymer. Number of wraps depeds on pipe pressure.

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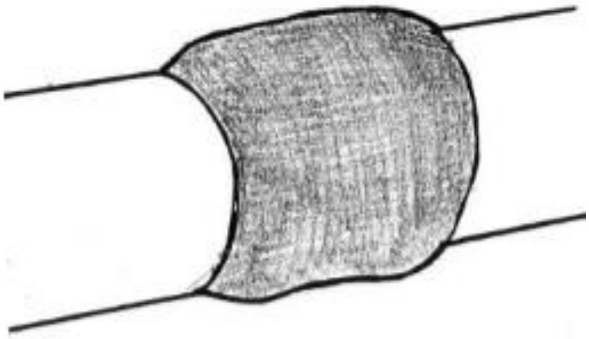
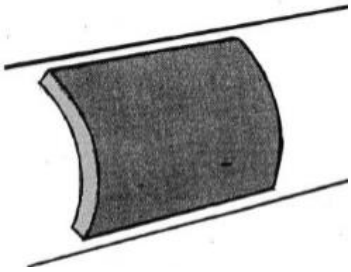


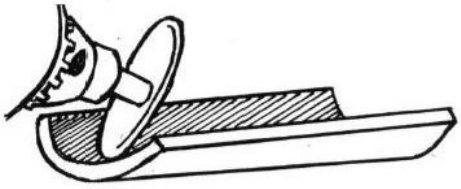
Add additional polymer compound to the repair location completely encapsulating the bandage. Smooth out the polymer and blend it in with pipe.

Metal doubler plates

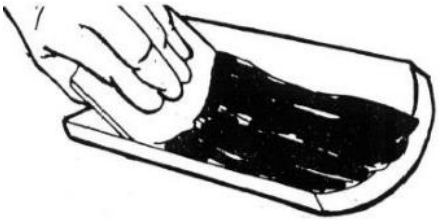
The two-part polymer compounds in combination with metal doubler plates and/ or synthetic fibres and woven fabrics have for many years provided a recognised emergency field solution for weakened and holed vessels and pipework where moderate pressure capacity is required.



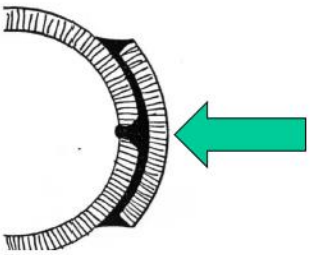
Fabricate an overlap plate from preferably same metal and with same radius and wall thickness as the pipe to be repaired.



Abrade inside of overlap and pipe surface.

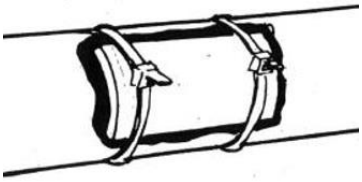


Measure up, mix and apply the polymer compound on inside of overlap plate and pipe surface.



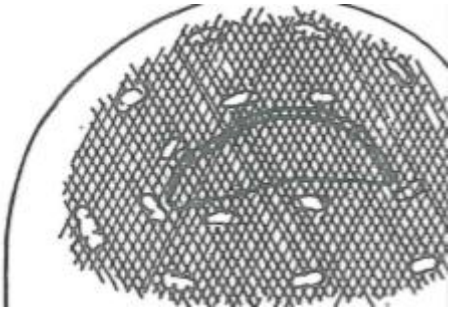
Press the plate firmly on to the pipe.

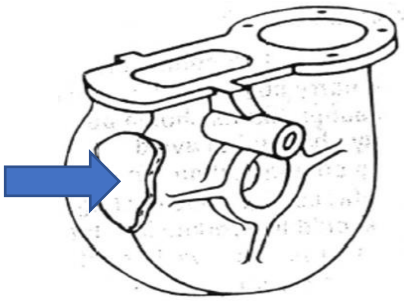
Keep overlap plate in place until polymer has set.



Measure up, mix and apply more polymer compound and apply over the doubler location and if need be also add reinforcement bandage to further strengthen the repair.

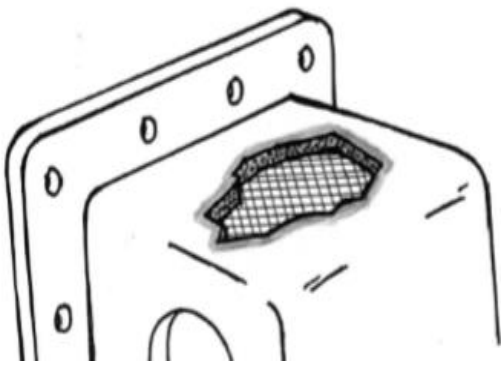
Metal mesh

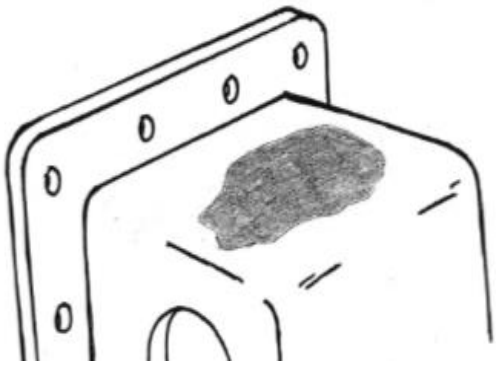




If a reinforcement plate is not feasible, heavy metal mesh can be a substitute. It can be fastened by tack welding to the external of the damaged section and then overlaid with the polymer compound.

If hot work like welding for tack welding is not appropriate use a fast curing polymer compound to keep the mesh in place.

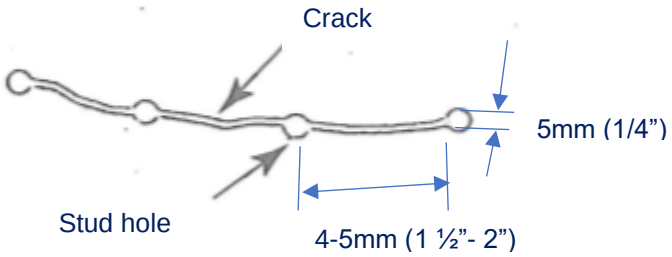




Place pre-cut mesh down in hole so that it makes contact with the fast curing polymer. Allow to dry. With mesh in place, measure up, mix and apply more polymer. Spread it out over the mesh and blend it in with edge.

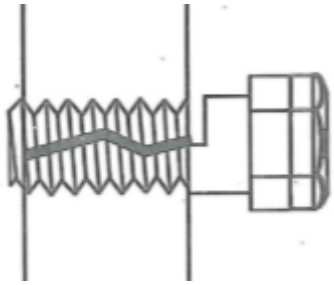
Cracks

Surface to a distance of 5-7cm (2- 3”) to each side of the crack should be thoroughly cleaned to remove grime, grease and accumulated dirt.
The end of the crack or cracks should be located using crack detector. Drill a hole 5mm (1/4”) at each end of the crack to stop it from spreading.
Drill holes 4-5mm (1 ½”- 2”) apart along the length of the crack.

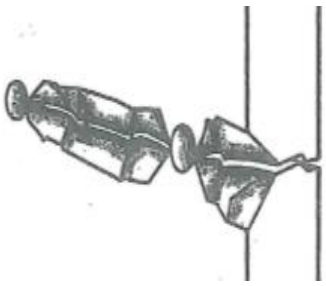


Hairline cracks is to be drilled in this way.
NB. The diameter of hole should be 5mm (1/4”) wider than the width of the crack. If the crack itself is 5mm (1/4”) wide then the hole should be 11 (1/2”) in diameter.

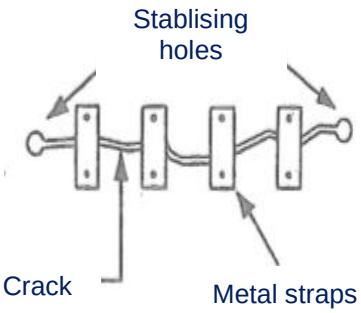
Holes should then be tapped with a coarse thread.



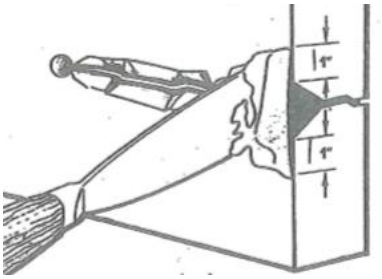
Bolts which have been partly sawn through should now be screwed into each hole, using the cut as a guide for installation depth.
The bolts can now be cut off, flush with the surface of the part.



Using a angle grinder or drill V the crack out between the installed bolts. The depth of the cut should be slightly less than half the wall thickness of the part. Ones again degrease the prepared area using a cleaner.

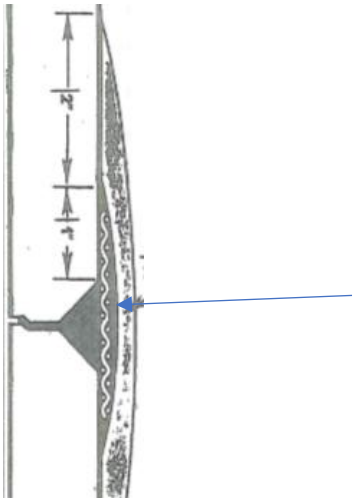


Where cracks are subject to high tensile stress, in addition to stabillising and opening the crack as above, the crack can also be “stitched” by fixing metal strips across the crack. These strips should be fixed with bolts. The strips should be coated with the metal grade epoxy prior to being tightened into position. The repair can then be completed as described below.



Application of the product

Mix sufficient of a metal grade epoxy to complete the repair. Using a spatula force the mixed product into the crack. Fill the V preparation and overlap the product by 2,5cm (1”) on either side of the V.

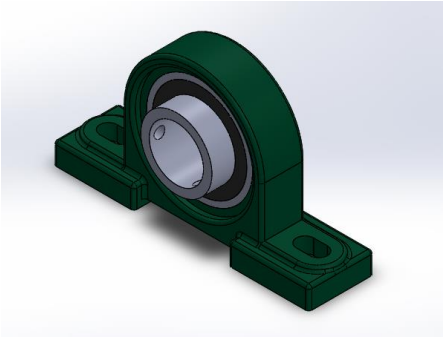


Cut a piece of reinforcement bandage 2,5cm (1”) wider than the V preparation. Lay the cloth over the applied product and embed the bandage into the product. A further quantity of product should be mixed and applied over the bandage building up to at least 6mm (1/4”) thick and overlap the edge of the reinforcement bandage. Feather out the edges of the repair using the spatula.

Reinforcement bandage
encapsulated into the product.

Bearing housings

Bearing housings are subject to abrasive wear as a result of a number of external factors. Wear increases the size of the housing allowing the bearing to move resulting in vibrations and shafts running out of true and other problems.



Overesize bearing housings can be brought back to correct dimensions by rebuilding the worn surface with a metal grade epoxy compound.

Surface preparation

Where the gap between the bearing and the housing is less than 1mm (0.04”), the housing should be enlarged by machining or grinding off approximately 1mm (0.04”) from inside of the bearing housing. The surface should then be roughened to provide a greater surface area thereby increase the adhesion of the metal grade epoxy.

If machining or grinding the housing is carried out with the housing in place be careful not to get metal fillings into the machinery. A rag stuffed into the housing is usually an effective method to prevent this from happening.

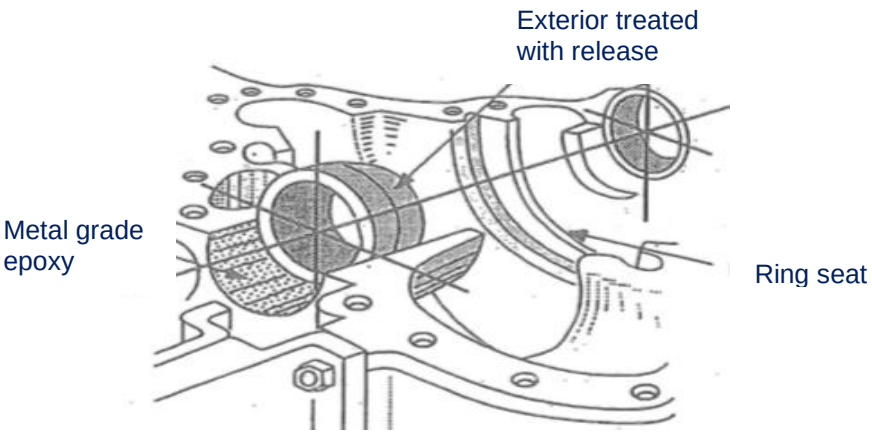
If the worn area is already greater than 1mm (0.04”), roughen and score the bearing housing surface with a file or rotary cutting/ grinding tool. As mention, avoid getting filings in the machinery.

Thoroughly degrease all surfaces with a cleaner.

The bearing should be used as a former. Apply a thin layer of release agent to the outer circumference of the bearing and overlap on to the outside edge of the bearing. This is done to prevent the metal grade epoxy product to stick to the bearing and allow it to be removed from the housing when desired.

Application of product

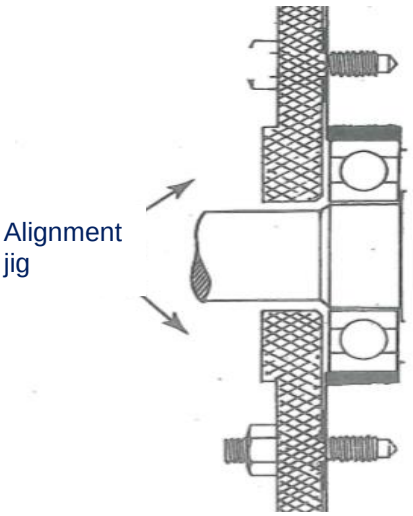
Mix sufficient product to fill the space between the bearing and the housing.



For insitu repairs, apply the product directly to the outer circumference of the bearing but only on the back half of the outer race. Remember the void between the bearing and housing must be completely filled. There should be no gaps. It is also essential that the metal grade product does not extrude onto or become applied, even by accident, to the backside of the bearing housing.

Push the bearing into the housing, forcing out excess mixed product.

Wipe off excess product from the side of the bearing. All the product should be on the circumference of the bearing, none should lap over on the side.



Aligning bearing housing

Immediately after placing the bearing in the housing, and removing the excess product, the bearing must be accurately aligned with the shaft.

The easiest methode of alignment is to reinstall the bearing on the shaft and allow the product to cure in that position.

If it is not possible to use this methode because of the type of equipment, a jig must be designed to ensure correct alignment.

Shaft repairs

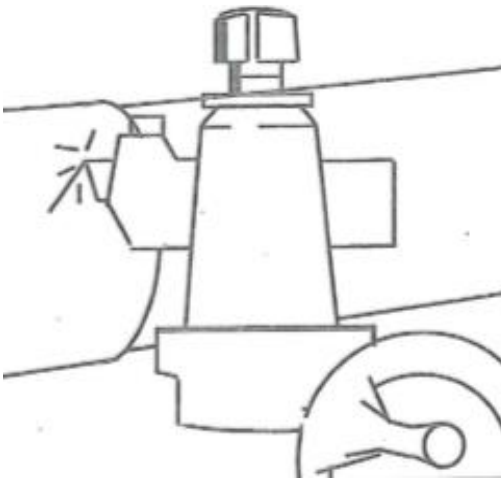
Metal grade epoxy materials can be used for three main types of repairs on shafts: the worn shaft itself, damaged and worn keyways, or damaged splines.

Shaft Bodies

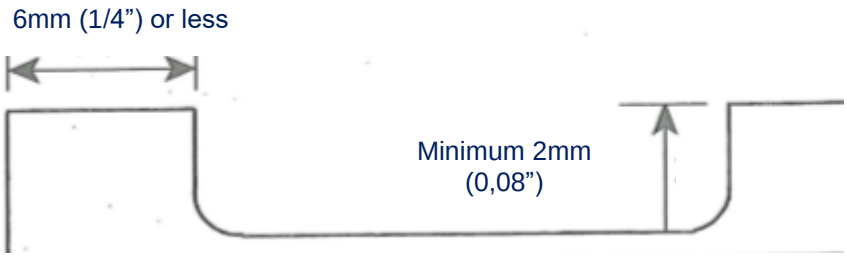
Shafts are worn by vibration, rubbing, abrasive materials, fretting and corrosion among others. Metal grade epoxy are used to rectify these defects.
The products normally used for this purpose are metal grade epoxy with normal curing time.
When rebuilding sections of worn shafts which run under packing, consideration should be given to the fact that the packing will cause friction, which in turn will generate heat that could affect the physical properties of the repair.
It is inadvisable to use epoxy materials to repair shafts which are so worn that after preparation more than 40% of the original diameter of the shaft has been removed.

Surface preparation

Any oil on the surface of the shaft should be wiped away using a clean cloth and a cleaner. If the shaft has operated in an oily environment, impregnated oil should be sweated out by warming with a blowtorch. The surface should again be degreased and the process repeated until a lint-free cloth soaked in a cleaner shows no further oil contamination.



The worn areas on the shaft should now be undercut using a lathe. The undercut should be at least 2mm (0,08”). If the shaft is already worn to the recomended depth then the area should only be machined to a course thread profile. A shoulder should be left at both ends of the cut to provide reinforcement for the repair and to serve as a guide when rebuilding the shaft. However, if the shoulder is 6mm (1/4”) or less from the shaft end, it should be removed.



Finish the undercutting by machining a coarse thread profile over the repair area. The rough surface cut increases the surface area and produces a surface for maximum adhesion of the epoxy product.

Undercutting depts

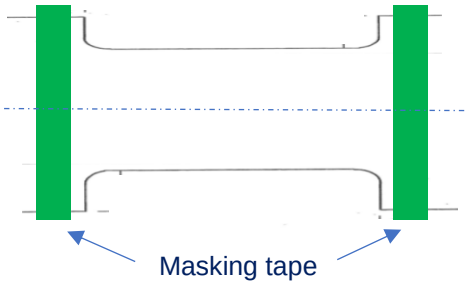
Shaft diameter	Undercut
13-25mm (1/2”- 1”)	2mm (0,08”)
Over 25mm (>1”)	3mm (0,12”)

The following guidelines should be followed for producing the coarse thread profile.

Shaft Diameter	50mm (2”) or less	Over 50mm (2”)
Threads	16 per 10mm (40 per “)	8 per 10mm (20 per “)
Pitch	0,64mm	1,27mm
Depth	0,30mm (0,0012”)	0,64mm (0,0025”)
Angle	90%	90%

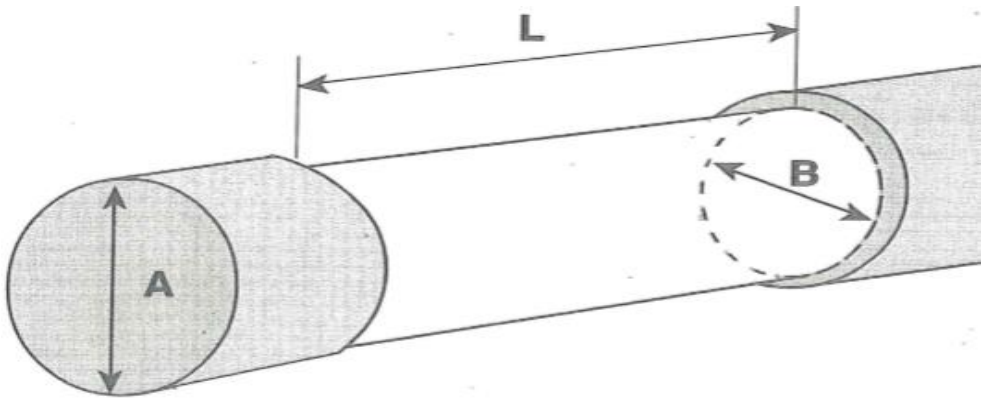
After machining surfaces should again be degreased.

Masking tape can now be wrapped around the shaft at the end of the repair area using 7- 10 revolutions of tape. This will allow for easier application of the epoxy product.

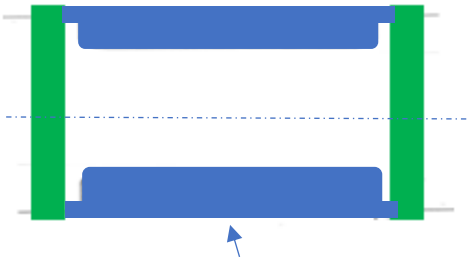


Application of product

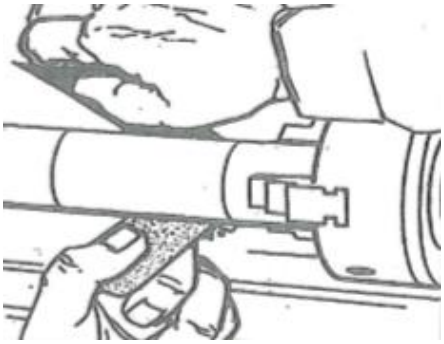
Sufficient product should be mixed to ensure that the area to be rebuilt is completely filled. Using the calculation A2 X L equals volume to be mixed, will ensure sufficient product is mixed.



The mixed product should now be applied to the prepared area, building up to the level of the masking tape.



Apply the product while the shaft is rotating in the lathe using spatula, pallet knife or straight edge. Make sure to press the product firmly and carefully onto the surface of the entire machined area to avoid air entrapment. Take specifically care to have product applied into the shoulder of the cut-out area and on to the level of the masking tape.



As soon as the material has gelled (product in semi-liquid state and set or become more solid) the masking tape should be removed.

Do not start machining before the product has cured suffisiently. Check machine data with the manufacturer.

Polishing of the surface with 400 to 600 wet emery paper can be carried out to improve the finish of the repair. If any air holes are exposed during machining these can be filled in with a fast curing epoxy.

Keyways

A key and keyway provides means of transmitting torque between a shaft and a hub. Through use, keywas become worn and will no longer effectively perform this function but this problems can be overcome using a metal grade epoxy.

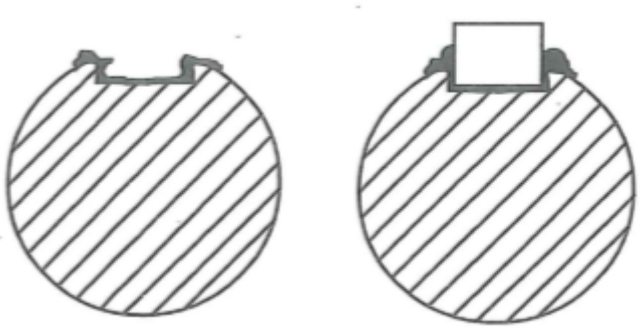
Surface preparation

Surfaces should be thoroughly degreased using a cleaner.Surfaces of the keyway should then be thoroughly roughened and scored with a file or a rotary grinding tool. All grinding swarf (metal fillings) and loose material should be removed and surfaces then degreased again using a cleaner.
A release agent should be applied to all surfaces of the key and to the internal area of the hub including the keyway. DO NOT apply release agent to the keyway or the shaft. The purpose of the release agent is to prevent the metal grade epoxy product from sticking to the key hub and the hub keyway. The release agent should be allowed to dry approximately 25 minutes before applying the epoxy product.

Applying the product

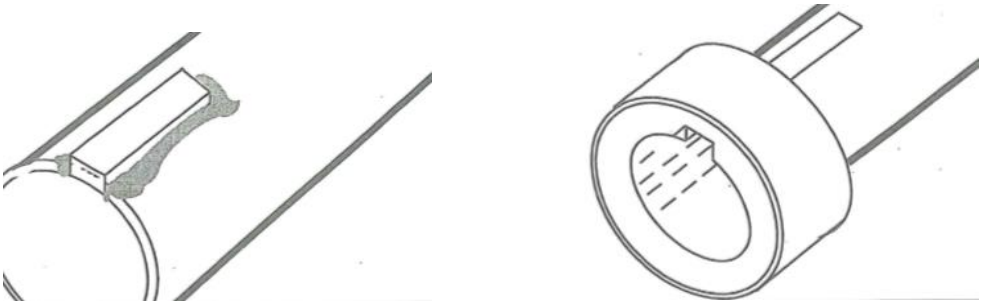
Mix sufficient product to complete the application a s described earlier.

The mixed product should now be applied to the prepared keyway. A thin coat should be applied to the bottom of the keyway and a somewhat heavier coat to sides. The mixed product should be pressed into the corners and against the side walls to force out the air. If to much product is applied on the bottom of the keyway it will raise the key too high and prevent it from sliding into the hub.



Positioning the key

Press the key into the keyway. This should cause the excess epoxy product to squeeze out of the keyway. Using the putty knife or spatula remove the excess product and shape the surface to the shaft profile.



Immediately reposition the hub on the shaft. This will properly align the key, shaft and hub.

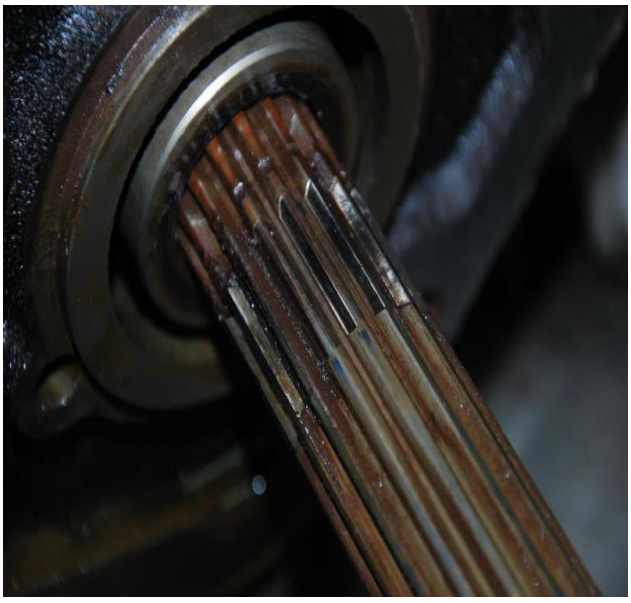
Once the product is cured the coupling can be put back in operation.

There is no need to dismantle the coupling since everything was coated with release agent to prevent components sticking together.

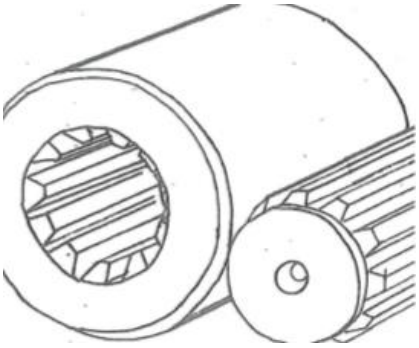
Splines

A spline is a series of parallel keys formed integrally with the shaft and mating with corresponding grooves in a hub or socket. Splines are used to transmit power. Like keyways the grooves into which the spline fits can become worn, creating unwanted play in the drive system.

Grooves in hub.

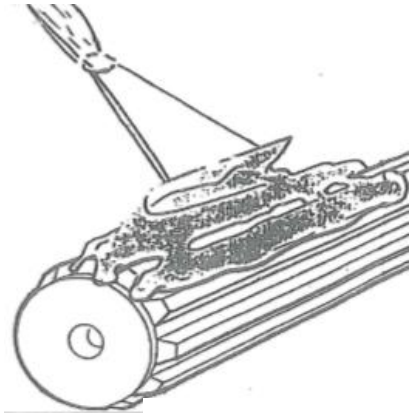


Spline.



Surface preparation

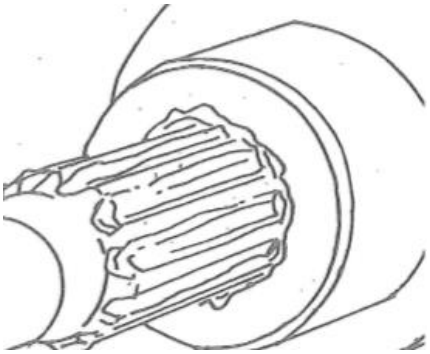
Separate the splined shaft from the hub then clean and degrease the surface ensuring complete removal of oil and grease.
File down the ends of the splines to give a 45 chamfer. This will prevent complete removal of the compound when the shaft is replaced into the spline hub.
The surface inside the hub should now be thoroughly roughened using a coarse file or similar tool. Surface should then be wiped with cleaner to remove any final traces of oil or grease.
Smooth down any high spots or rough areas on the spline shaft by filing or sanding then treat shaft with a release agent.



Product Application

Sufficient product of a metal grade epoxy to complete the the application should be mixed as previously described.
The mixed product should now be applied generously to the splined shaft by spatula. The product should not be applied into the hub, unless the hub is badly worn.

Repositioning the spline



The coated spline shaft can now be pushed into the prepared hub. The excess product will be scraped off by the hub as the shaft is installed. Extra pressure can be applied to the shaft on insertion to extrude the excess product from the hub.

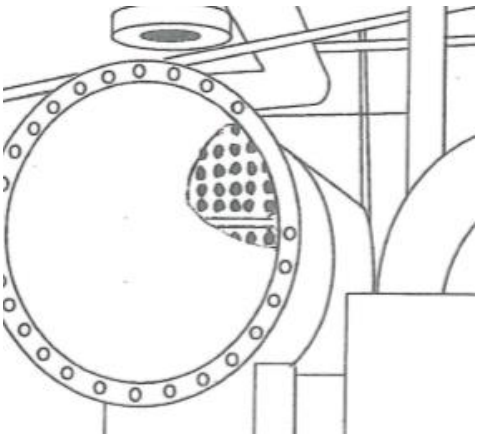
Excess product should be wiped from the shaft which can then be finally cleaned with a cleaner. The worn area should now be completely filled which will eliminate play once the product is cured.
Once the repair is cured the coupling can be put back into service.

Dismantling

Should it be necessary sometime in the future to disassemble the spline and the hub they can be separated.
Before taking the components apart it is advisable to mark the position of the spline and hub before separating. The reason for this is that the repair is a custom fit and the spline can only go back into the hub in one position.

Heat exchangers

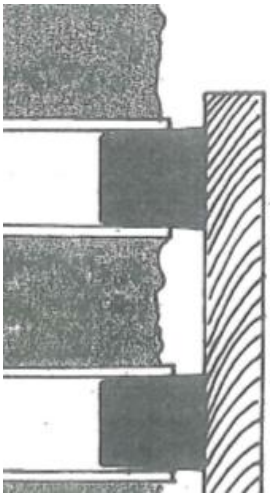
Heat exchangers, chillers and condensers are constructed of bundles of copper tubes held together by tube plates, all of which are contained in a solid metallic cylinder. The purpose of the unit is to transfer heat.



The tube plates are subject to heavy corrosive attack, due to the tubes being copper and tube plates are of a different metal. Dissimilar metals in contact will cause galvanic corrosion. The whole corrosion process is accelerated by the heat and wet condisions inside the equipment.

If left unattended, the corrosion will completely destroy the tube plate. There are two ways to maintain the tube plates.

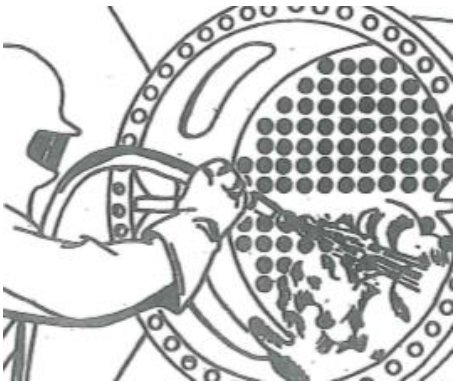
1. A metal grade or ceramic grade epoxy product can be applied to a new tube plate before the unit is put into service and it is regularly maintained, thus preventing the tube plate from becoming corroded.
2. Where the tube plate is put into service without protection and once become corroded, the surface can be rebuilt with an epoxy repair system and its working life extended.



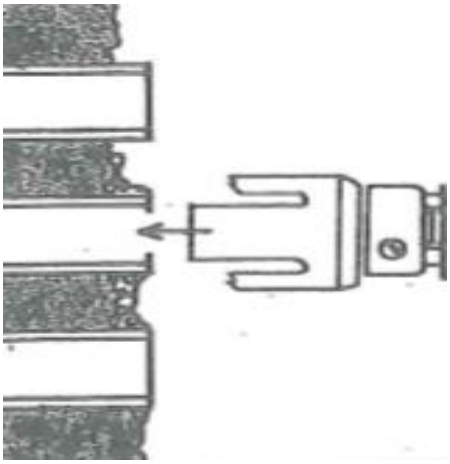
Surface preparation of new units

Prepare both ends and all components of the unit before applying product. Remove the end plates and baffle.

Insert a suitable stopper into the end of each tube so that the stopper stands proud of the tube equal to the thickness of the system being applied. The stopper should fit snugly into the tube. A wooden bar should be used to push the stoppers in to the current uniform level.



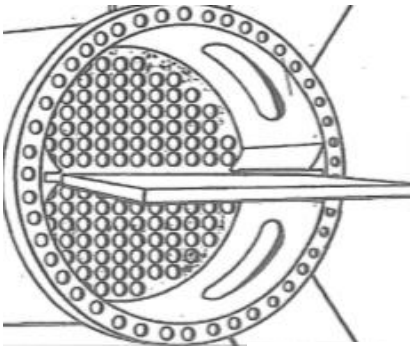
Once the stoppers have been installed, the surface should be abrasive blasted (SA 2,5). After thorough blasting, blow all the debris off the surface with clean oil free air. Surfaces should finally be thoroughly degreased using a cleaner.



Surface preparation of worn units

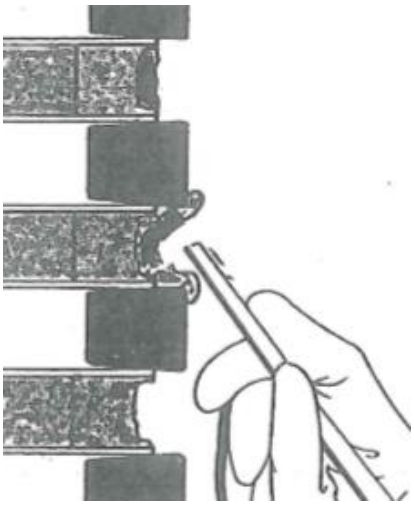
Prepare both ends and all components of the unit before applying product. Remove the end plates and baffle from unit. Blow out the standing water in tubes with air until the tubes are dry. Degraded metal should be removed from around the tubes using a proper size tube saw, to cut a groove around the end of each tube. The degraded metal can now be chiselled from between each tube. Care must be taken not to damage the tube ends.

Insert a rubber stopper into the end of each tube using the most protruding tube as a guide level to which the stoppers should be pressed in. Once the stoppers have been installed, the surface is abrasive blasted. The blasted surface should then be sweated to remove any ingrained salts then re blasted if salt is present. After thorough blasting, blow all debris off the surface with clean oil free air. Thoroughly degreas the area using a cleaner. If delays between blast cleaning and application of repair material occur and the surface flash rust, the surface must be flash blasted to remove the rust.



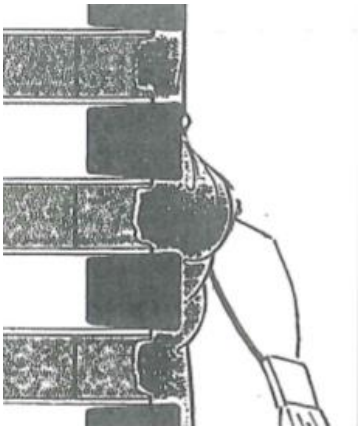
Surface preparation other components

The baffle plate, recessed area and end covers should be prepared as detailed as previusly described. The baffle plate is found in the recessed area of the unit and usually can be slid in and out. Remove the baffle plate before preparing the surface of the plate or the recessed area. Do not put the baffel plate back in until the coating job is complete. There is an inlet and outlet opening in the recessed area. When preparing the surface, reach as far down into the line as possible.



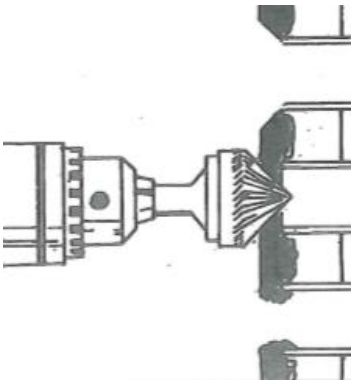
Application of product

Tube plates: Mix the appropriate quantity of metal grade or ceramic grade compound epoxy to fill any eroded/ pitted areas in old tube plates.



Two coats of liner should be applied to the tube plate. Apply the first coat evenly over the prepared/ re-built surface whilst the compound is still soft. It is important to press or force the product around each stopper to force out any entrapped air. This can be done using a small spatula or a stiff piece of plastic, wood or metal that fit between the stoppers. Draw the spatula / tool down each row, pressing down and around each stopper. Do this both in the north – south and east - west direction. As soon as the first coat is set apply the second coat and fill to the top of the stoppers. Smooth level with the top of the stoppers. As soon as the product is set it can be overcoated with a metal or

After 24 hours the stoppers can be removed using a ball peen hammer, gently tap each stopper to break the bond between the cured product and the stopper. The stoppers can then be blown out from the tubes. If this is not possible, they may be forced out by a rod from the opposite end of the tube. Remove all stoppers. Do not throw them away as they may be reused in future repairs.



The end of each tube hole can be chamfered to get rid of excess material and to smooth out the hole using a small drill with a conical grinding bit.

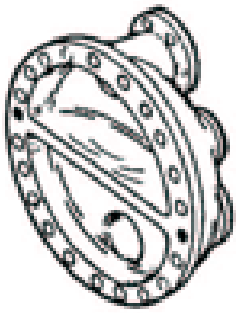
Recessed area (if applicable)

Mix sufficient product to coat the recessed area: baffle plate holder and inlet and outlet pipe. Apply the product using a spatula or putty knife. To give a uniform even coating, a stiff brush may be used to give a smooth finish. Coat the recessed area and the inside of the inlet and outlet pipe, but no further than the prepared area. Coat the baffle plate holder, but do not coat the groove into which the plate slides nor the outside end of the holder way up to the end cover.

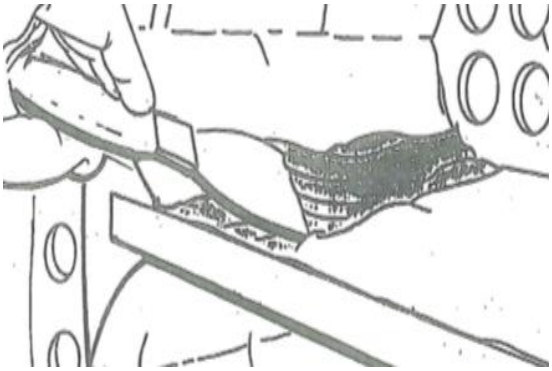
Baffle plate

Sufficient product to coat the baffle plate should now be mixed. Apply two coats as explained before. Do not coat the edges that slide into the baffel plate holder nor the ends which come into contact with the tube plate end cover.

End cover



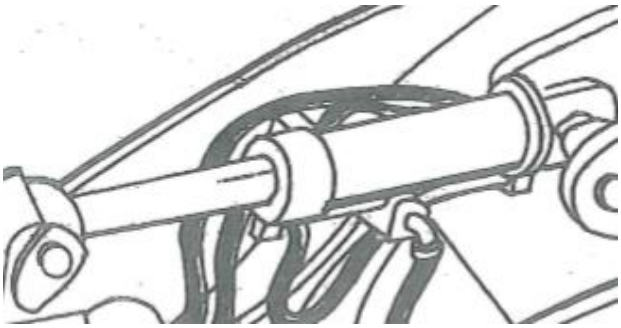
Mix sufficient product to coat the end covers and apply two coats as explained before.



Reassembly of equipment

Once the product has hardened in accordance with the cure times on the products tech sheets the equipment can be reasambled. Slide the baffle plate back into the recessed area. Apply metalgrade or ceramic epoxy between the baffel plate and the groove to seal it.

Hydraulic/ Pneumatic rams and rods



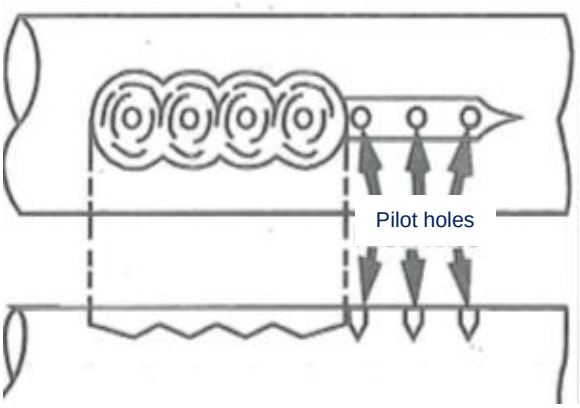
Hydraulic/ Pneumatic rams and rods

Reciprocating rods and rams such as those found in pumps or hydraulic / pneumatic equipment become scratched or scored. The damage is normaly found along the length of the ram rather than around the circumference. These scratches and scores allow fluide or air to escape from the cylinder, reducing lift capacity or efficiency.

Surface preparation

Thoroughly degrease the ram or rod using a cleaner. Degreasing should also be carried out on pneumatic system as well as systems using water based or non-flammable hydraulic fluids.

Absorbed oil from surfaces which have been immersed should be removed by heating to sweat out oil. First wipe off the excess oil with a cleaner. Then heat the surface again to force the oil out of the pores of the metal. The heating can be done in an oven, with an open flame or an electric heat gun. Allow the surface to cool and wipe it down again with a cleaner. Repeat the sweating process until all of the oil has been removed. NB. Do not use an open flame on a surface which may be damaged by heat or is combustible nor in an area where there is a flammability or explosive potential.



Using a small drill, a series of holes should be drilled along the length of the score. This pilot holes will prevent the larger drill used to open out the score from travelling and assure correct overlapping of holes.

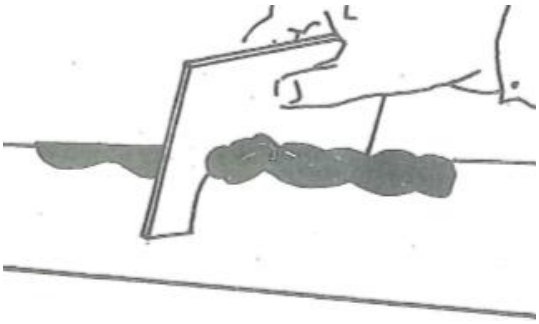
Using a drill bit 50% greater than the with of the score, the score should be opened out by drilling holes using the following table as guide:

Shaft diameter		Depth	
mm	Inch	mm	Inch
13 to 19	½ to 3/4	2	0.0625 (1/16)
Over 19	Over 3/4	3	0.125 (1/8)

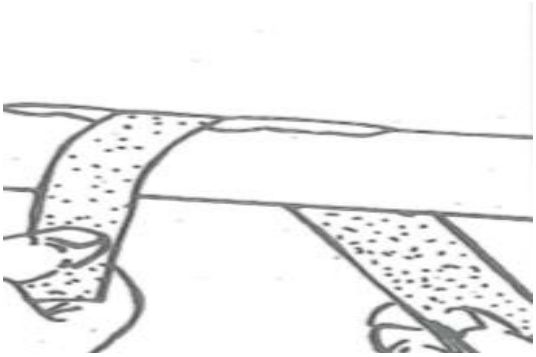
Once the holes have been drilled, remove all swarf the degrease the area with a cleaner.

Application of product

Measure out sufficient of a metal grade epoxy product and mix thoroughly as previously described. Using a spatula, applicator tool or putty knife, press the mixed product firmly into the crevice taking care to avoid air entrapment. The mixed product should be filled proud of the prepared surface to allow for finishing.



A plastic or metal template to the profile of the ram can now be drawn over the repaired area to remove the excess product. Warming the template beforehand will reduce the possibility of roughening or pulling the product of repaired area.



Once the repair is cured the area can be finished to the original profile using 400 to 600 wet emery paper. During this process, care should be taken to not scratching the chrome plating on the ram or rod.

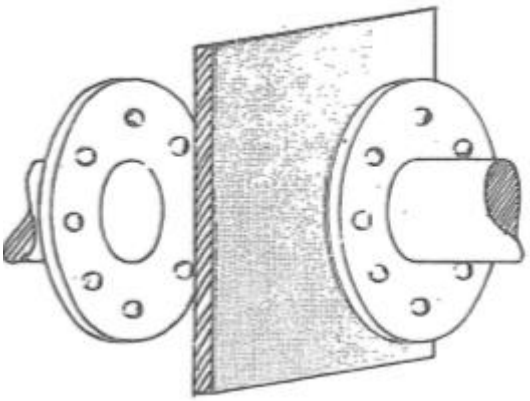
NB. The repaired area can NOT be chrome plated, flame sprayed or hard coated.

Allow the product to develop full physical properties before returning the ram to service. Check tech sheet for product used.

Flanges and mating surfaces

Flanges and mating surfaces on pipes, pumps and valves can become distorted and scored trough repeated dismantling for maintenance and cleaning, that result in leaks and loss of efficiency.

Damage to both mating surfaces.

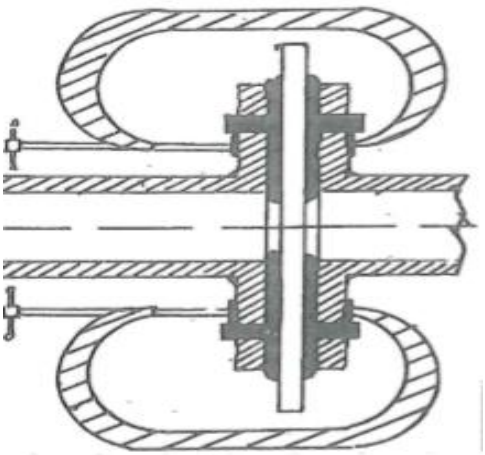


Surface preparation

Both surfaces should be thoroughly degreased using a cleaner. Surfaces should be abraded by grinding and then cross scored to ruffen the surface. Bolt holes in the flanges should now be plugged using wooden pegs, putty or plasticine. A flat metal plate larger than the external diameter of the flanges should now be coated on both sides with a release agent.

Product application

Mix sufficient of a metal grade epoxy to complete the application. The mixed product should now be applied by spatula or pallet knife to the two mating surfaces, to “wet out” the entire surface, tapering the application from the centre to the edge of each face.



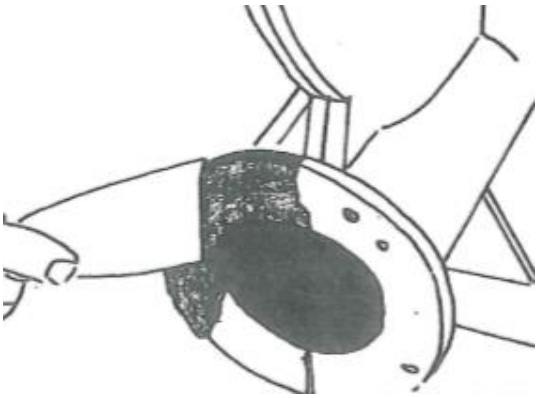
The treated metal plate should now be held between the two faces and the two faces squeezed together so that the metal grade product product is evenly spread over the surface. The two faces should then be clamped together using G clamps, with further mixed product being squeezed out. The excess materiel should be scraped away and the clamps left in position until the product has cured according to the products tech sheet information. Ones cured the clamps can be removed and the metal plate taken away. The plugs can then be removed from the bolt holes and the flanges reassembled.

Single face repairs

When damage to the flange faces is slight, or mainly affects one of the two flange faces only one face needs to be repaired with a metal grade product and the other can be used as a former.

Surface preparation

The most distorted/damaged flange face should be thoroughly degreased and abraded as previously explained. The other face should be thoroughly cleaned and then then treated with release agent. Also, the flange coupling bolts should also be thoroughly cleaned and treated with a release agent.



Product application

Mix sufficient of a metal grade epoxy to complete the application. The mixed product should now be applied by spatula or pallet knife to the abraded flange surface. The two flange faces should be pressed together and the coupling bolts tightened into position squeezing out the excess product. The excess product should be removed and surfaces wiped clean. The two flanges should be allowed to cure in accordance to the products tech sheet information. Once cured the flange can be opened up and “dressed”, before beeing reassembled and put back in service.

Pump housings, impellers, fans and propellers

During service pumps housings, impellers, fans and propellers suffer from erosion and cavitation all which reduce the effectiveness of the component. Metal grade, and specially the ceramic grade epoxies can with good results be used to repair and remedy these products.

Surface preparation

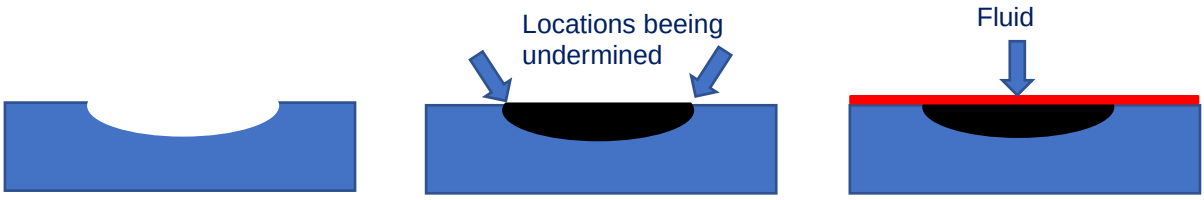
All surfaces should be abrasive blast cleaned. Alternatively, a die grinder, needle scaler or angle grinder may be used. If grinding make sure the surface is roughened, not polished. Where grinding or needle gunning is used, the surface should be cross scored to improve adhesion. On pitted surfaces it is essential that all pitted areas are thoroughly cleaned.

Components which have been operating in sea water or chemical environments should be sweated to ensure complete removal of impregnated salts and other substances and then re - blasted. Surfaces should be coated within 2 hours of blasting to prevent flash rusting. Surfaces should now be thoroughly degreased using a cleaner.

Product application

Eroded surfaces should be rebuilt with either a metal grade or a ceramic grade compound epoxy. If cavitational wear the best product to use will normaly be a ceramic grade epoxy. Mix according to information given on products tech sheet. The mixed product should now be applied to the prepared surface by spatula or pallet knife. The product should be pressed firmly into the surface to prevent entrapment of air, paying particular attention to pitted areas. The surface should be finished to approximately contours of the component and the exact shape can be achived by using a thick sheet of plastic pressed firmly into the surface following the profile. Any excess product squeezed out should be carefully removed and the repair allowed to cure in accordance with information on products tech sheet. After curing the sheet of plastic can be removed.

If required to prevent future erosion and corrosion the whole surface can finally be coated with a fluid ceramic grade (liner grade paint). This can be of particular importance in order to seal the transfer sone between base material and the epoxy compound from being undermined by further cavitation wear.



Base materials original wear

Wear filled inn with repair compound

Base material and compound overlaid

The fluid ceramic grade should be mixed according to information on products tech sheet. It can be applied to the surface of the ceramic grade compound product when it has set. Apply the fluid using a brush. Fluid coatings will often develop pin holes. It is therefore good practice to apply a second coating. A second coating should be applied as soon as the first coating has set. Some manufacturers offer fluid ceramic coatings with different collours in order to better distinguish treated and non-treated locations.

If there is no heavy wear that require a ceramic grade compond material to be used, a fluide ceramigade product can be applied directly to the base material. If so, the surface preparation should be the same as described for use of the ceramic grade compound epoxy. Note: If delays have occurred between initial preparation and application of the coating system which have allowed surfaces to flash rust, surfaces should be brush blasted prior to coating application to remove any flash rusting.

Once the applied system has cured the component may be returned to service.

Ships rudder repair

NB. Before making application to do repair towards rudder, consult the classification society.

In service, the ships rudders become pitted and eroded and these areas can be rectified in the same way as impeller and propellers described in previous chapter. One other area frequently causing problems are worn pintle housings.

Oversize bearing housings for rudder.

If possible, machine the bearing leaving a minimum 3mm (0.12”) space to be filled in with a metal grade epoxy. The interior of the pintle housing should be abrasive blasted (SA 2,5) to give a coarse surface profile. Surface should be sweated as previously described to ensure any entrained salts are removed. Degrease prepared area using a cleaner. Surface should once again be re-blasted and sweated. Repeat this sequence until all salts are completely removed. Make a final degreasing using a cleaner. The pintle should be treated with a release agent.

Product application

The metal grade epoxy should be mixed according to the manufacture’s tech sheet information. The mixed product should then be spread onto the internal surfaces of the prepared housing and onto the external pintle using spatula or pallet knife. The pintle should now be jacked into position and correctly located. The excess metal grade epoxy which is squeezed out when the pintle is being inserted should be removed before the product cures. Once the product has cured as informed in the products tech sheet, the repair can be put back in service.

There are a number of repairs that can be performed on ships rudder using epoxy materials:

Tail shaft / stock, stock cone, heel pin derrick, heel bushing and stock bearing. Procedures available on request.

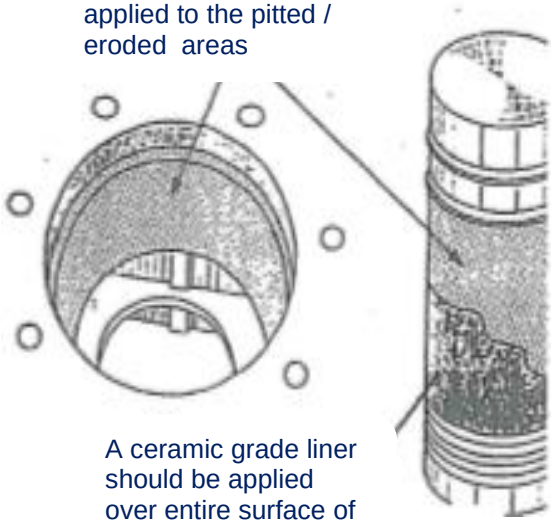
Engine parts

Worn and pitted wet liners

Surface preparation

Surfaces should be cleaned and abrasive blasted ensuring that deep pits are thoroughly cleaned and corrosion products removed. Surfaces should now be degreased with a cleaner.

A ceramic grade compound should be applied to the pitted / eroded areas



A ceramic grade liner should be applied over entire surface of the liner.

Product application

Pitted areas should first be made good with a ceramic grade compound. Product should be measured and mixed as stipulated in product tech sheet. The product should then be applied to the pitted / eroded areas using a spatula, forcing the product into the pits thereby forcing out entrapped air. The applied material should be finished off to the original dimensions of the liner and allowed to set.

Next step is to appy a ceramic grade liner. Product should be measured and mixed as stipulated in products tech sheet before beeing applied over entire surface of the liner. Where delays have resulted in either flash rusting of exposed metal or the ceramic grade compound becoming hard then surfaces should be reblasted before the ceramic grade liner is applied.

Once the applied products have cured in accordance with the products tech sheets the repaired liner can be refitted to the engine.

Erosion or corrosion of liner seats

Surface preparation

The surface of the seat should be prepared using a conical grinding wheel or needle gun to produce a coarse profile and remove all corrosion products. Sweating and re - grinding may be necessary to remove it all. The surface should then be treated using a universal cleaner. The liner landings should be treated with a release agent.

Product application

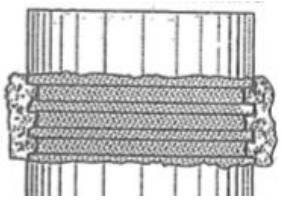
Sufficient metal grade compound epoxy material should be measured and mixed according to tech sheet information. The product should be applied to the seat area and allowed to become tack- free. The liner can then be carefully positioned, care being taken not to displace the product from the seat area. When the product has cured sufficiently (according to tech sheet information) the liner can be removed to gain access to excess product squeezed out so that it can be ground away.

Worn liner seal housings

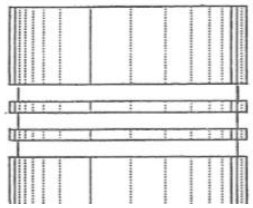
Surface preparation

Surfaces should be thoroughly degreased using a cleaner. The worn housing should now be abraded by grinding or needle gunning. Surfaces should then be degreased again.

Liner before machining



Liner after machining



Product application

Sufficient metal grade compound epoxy material should be measured and mixed according to tech sheet information. The product should be applied into the worn housing so that it stand proud of the liner surface.

Once the product has cured sufficiently for machining the housing can be machined back to the original dimensions and new seal groves cut into the cured product.

The seals can now be refitted and the component returned to service.

Valves

Eroded gate valves

Surface preparation

All corrosion products and degraded metal should be removed by grinding and needle gun, taking care not to damage brass sealing ring. Surfaces should now be sweated to remove any ingrained corrosion products and salt. Further grinding and abrasion should now be carried out to ensure a coarse surface profile. Prepared area should now be degreased with a cleaner.

Product application

Sufficient ceramic grade compound epoxy material should be measured and mixed according to tech sheet information. The mixed product can now be applied to the prepared surface using a spatula or pallet knife. A thin coat should first be spread thinly over the surface to avoid air entrapment, espesialy in areas with deep pittings. Having secured the surface the areas can now be filled with product to requirement and smoothed off just proud of the sealing rings. Once the product is cured sufficiently for machining the repaired area can be dressed back to correct dimensions using an electric sander.

Worn valve seats (Non internal combustion type)

Surface preparation

Surfaces should be thoroughly degreased with a cleaner. The valve seat should be prepared by grinding and abrading. Surfaces should ones again be degreased. The valve seat itself should be coated with a release agent.

Product application

Sufficient ceramic grade compound epoxy material should be measured and mixed according to tech sheet information. The mixed product should now be spread onto the surface using a spatula or pallet knife. The valve should now be fully closed using sufficient pressure to squeeze out excess product. The excess product should be carefully removed taking care not to disturb the valve. Once the product has cured the valve can be opened or removed and the cured product dressed to remove any residual excess material. The valve can now be reassembled and returned to service.

Rubber repairs

Elastomers (synthetic rubber) available as compound grade and fluid grade material can be used for a wide range of repairs to rubber components including hoses, gaskets, rollers and other flexible materials.

Initial preparation

It is important that any loose contamination on the rubber surface be removed. This can be accomplished by high pressure hosing, scrubbing with cleaning solutions. Where the component is fabric reinforced the reinforcement must be dried if this has become saturated with water or other chemicals. The prepared area must be greater than the area to be repaired. Any loose or fraying rubber or fabric which may hinder good adhesion must be cut away.

Undercutting

To give good adhesion and to eliminate the possibility of the repair material being lifted out it is advisable to undercut the parent rubber material to allow for reasonable thickness and to provide good addition at the edges of the repair. Ideally the cut should be made to produce a joint with the parent rubber of at least 90 degree. Preferably the undercut should be so that the rubber repair is dovetailed into the parent rubber, eliminating any possibility of the edges of the repair being picked up.

Hand tool for abrading rubber (rubber rasp).

Abrading the surface

This is the most critical stage in the surface preparation of rubber surfaces. To obtain optimum results, the rubber must be abraded to remove any deteriorated rubber and to produce a rough surface to which the repair product can be bond. The choice of tools is extremely important and there are several tools that can be used for this purpose. The most versatile and readily available is a rotary wire brush. The wire brush itself must be in good condition so that when used on rubber, the actual surface is broken and not just polished as can happened with worn wire brushes. Coarse grinders can also be used to prepare rubber surfaces, but care has to be exercised to ensure that the rubber surface is actually roughened and not polished.

The rubber surface must be roughened, not polished.

Degreasing

Once the surface has been roughened, the surface should then be wiped with a cleaner to ensure any oil or wax that may have been brought to the surface is removed. Surfaces must then be allowed to fully dry prior to the application of the primer. Where fabric reinforcement has been exposed, extra time should be allowed for this drying process, since the fabric may have absorbed a considerably amount of the cleaner.

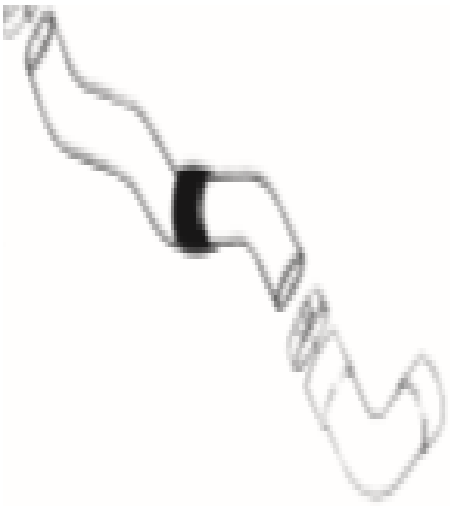
Conditioning

Ensure complete wetting of the surface applying the primer but avoid ponding in any surface depressions. It is essential that the thinnest possible layer of primer is applied to the surface. Use a stiff brush and work the primer into the abraded rubber surface.

Product selection

Depending on application one must then decide on type of elastomer product:
As compound grade or fluid grade
Shore A hardness (Shore A 60 is like soft rubber; shore A 90 is like the hard rubber used in car tires).
For the following application a Shore A 60 elastomer compound and fluid products have been used.

Repair of low-pressure hoses



Repairs cannot be carried out whilst the hose is under pressure. Pressure must be removed and the hose drained before proceeding.

Surface preparation

Follow the preparation steps informed (Initial preparation, abrading, degreasing, conditioning).

Product application

Select a compound grade Shore A 60 hardness product. Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet. Using an applicator apply the mixed product to the prepared areas around the damage. Make sure to press the product well into the surface. Wrap a reinforcement bandage into the repair squeezing product. Add more product on to the repair area encapsulating the bandage completely. Extra layers of reinforcement bandage and product should be applied to strengthen the repair so that the thickness of the repair is at least 50% greater than the original wall thickness of the hose. A sheet of polyethylene can be pressed over the surface of the repair. This sheet can be worked with fingers to produce a neat smooth repair contoured to the hose. When the repair has cured the piece of polyethylene sheeting can be peeled away to leave a smooth surface.

The repair should be left to cure before returning to service. Details to be found in the selected product tech sheet.

Repair of pump diaphragms

Diaphragm pumps, also known as membrane pumps, are used to transfer different types of liquids. The pneumatic system cannot cause sparks, and makes diaphragm pumps suitable for areas with explosion risk. The pumps are highly reliable and easy to maintain, but periodic inspection is still needed to prevent defects.

Surface preparation

Note that the damaged diaphragm should be removed from the pump and scrubbed with a detergent solution followed by rinsing in clean water. Any loose rubber should be cut away with a sharp knife, so that the wire reinforcement is exposed but not severed. The edges of the worn area should be undercut and the diaphragm edges should be mechanically wire brushed to produce a rough surface as previously explained. A thin coat of primer should be applied to all exposed areas of the wire mesh reinforcement of the diaphragm edge and allowed to dry.

Product selection

For the following application a Shore A 60 elastomer fluid product have been used. Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet. The mixed product should be forced into any split areas with a stiff bristled brush. A reinforcement bandage should then be stippled into the product. Further product should then be applied to completely cover the reinforcement bandage. A further coat of the fluid grade product should be applied over this and around the diaphragm edges and the entire repair allowed to cure in accordance with the product information tech sheet before being put back into service.

Patch repairs on rollers

Surface preparation

The edges of the damaged area should be undercut with a sharp knife. From there onwards follow the preparation steps informed previously (Initial preparation, abrading, degreasing, conditioning).

Product selection

Select a compound grade Shore A 60 hardness elastomer product. Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet. Using an applicator apply the mixed product to the prepared areas around the damage. Make sure to press the product well into the surface to avoid air entrapment, which could weaken the repair. The repair can be shaped by stretching a heavy-duty polyethylene sheet over the surface. Once cured the sheet can be removed and a perfectly smooth finish will remain.
On grooved rollers, a straight edge can be used to finish the repair, flush with the surrounding surface can be left proud then machined to the correct profile. Where machining is involved, a sharp tool should be used and the cutter should be adjusted so that the rubber swarf is removed as a continuous thread to give the best possible finish. A feed rate of 5- 10 thou./rev with a surface cutting speed of 200- 400ft./min should be used. Small repairs can be finished with abrasive paper.

Rebuilding worn rubber impellers

A compound grade elastomer product is ideal for repair rubber impellers operating in abrasive slurries. The impeller should be thoroughly washed down with a detergent solution followed by housing with clean water ensuring that no foreign particles are wedged between the rubber and the iron core. Any loose areas of rubber should be cut away and the edges of the areas undercut. Surfaces should now be thoroughly roughened with a rotary wire brush then degreased using a cleaner. The surface should then be allowed to dry.

Any exposed metal should be cleaned as above and thoroughly roughened preferably by grit blasting to remove loose rust and to give a key. All metal and rubber areas should then be primed. The primer should then be allowed to dry.

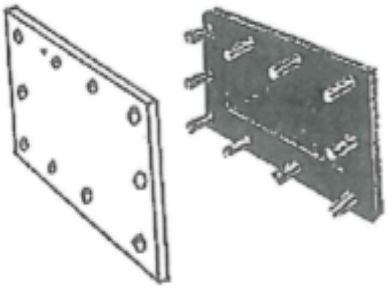
To obtain accurate contours, light gouge aluminium or plastic should be bent to required dimensions. The internal areas of the former should then be treated with dimensions a release agent and allowed to dry for 15- 20 minutes.

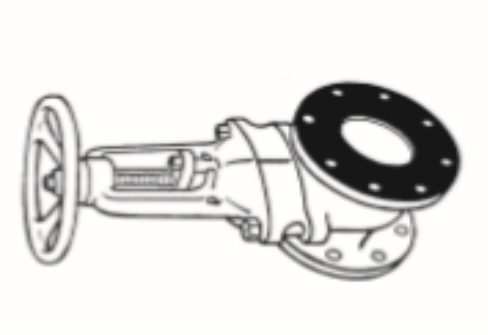
Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet. Using an applicator apply the mixed product to the prepared areas around the damage. Make sure to press the product well into the surface to avoid air entrapment, which could weaken the repair.

The repair must then be allowed to cure as detailed on the products tech sheet. The former should be peeled carefully from the surface after the repair material has cured.

Gaskets between mating surfaces.

The two mating surfaces should be disconected and separated and the old gasket removed. The susrfaces should then be troroughly cleaned to remove all contaminationand degraded gasket.



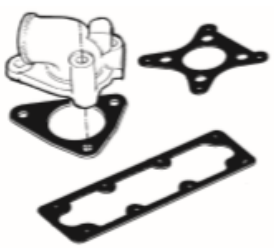


Product application

Pegs treated with release agent should be fitted into the bolt holes, and the flange surface should also be treated with release agent which should be allowed to dry. Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet and then spread with a spatula on to the flange face taking care that no air is trapped. The pegs can now be removed carefully and the two faces bolted together with bolts being equally tightened 95%, squeezing out excess material. Excess material should be scraped away and the product left to cure. Once the product cured the bolts can be carefully tightened and a new gasket is formed.

Moulding a gasket

The worn/ perished rubber gasket/ seal should be removed from its seating and surfaces of the seating completely cleaned. The cleaned surface should then be treated with release agent and allowed to dry. Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet. A thin coat of fluid grade elastomer product should be brushed onto the sides of the seating surface. The reminding material can then be poured carefully into the seating taking care to minimise and air bubbles. Gentle vibration of the component will bring to the surface any bubbles. The seating should be completely filled leaving the product slightly proud of the surrounding metal. Once the product is cured the component can be assembled.



Conveyer belt repair

Broken idler rolls or jagged chunks of stone, coal, salt, and other materials can take a heavy toll on a conveyor system.

Rubber repair elastomers have also been formulated for applications on vertical or horizontal surfaces for “on-the-spot” conveyor belt rubber repairs.

Follow the preparation steps informed previously.

Conditioning in the form of applying a primer, sometime referred to as promoter, is a one-part, brush-on type. This will strengthen and enhance the bond of polyurethane resins to the rubber. Instructions for use:

Ensure the repair area is clean and free of any corrosion, oil or moisture. Use a slow-moving rubber grinding disk to roughen the belt. Use a buffing disk with a 12 or 24 grit texture if possible. Pour out a small quantity of primer onto the repair surface. Brush evenly across the entire bonding surface in a thin layer using a clean, soft bristled brush. Leave the primer to dry for 6 - 8 minutes ((20 ºC/ 68º F). If you can leave your fingerprints in the primer, it has tacked sufficiently. If you can easily move your finger around in the primer you do not have sufficient tack.

Sufficient product to complete the repair should be mixed in accordance with the selected product tech sheet. Apply a thin layer to “wet out” the surface first. Thereafter add a liberal amount and spread evenly using a spatula.

Rubber repair elastomers are often used in combination with bolt-on fasteners to perform splicing of conveyor belts. Repairs can also be performed using repair patches and strips with bonding layers.

APPENDIX: STANDARDS FOR COMPOSIT REPAIRS

This is extracted from a document produced by ACORES (Association of Composite Repair Suppliers)

The relevant, applicable standard for composite repair systems is ISO/TS 24817 - Composite repairs for piping. The scope of ISO/TS 24817 covers the following components:

- Pipelines
- Pipework including straights, elbows, tees, flanges, reducers, valve bodies
- Tanks and vessels including nozzles and attachments

The content of ISO/TS 24817 includes details on:

- Qualification requirements; tests suppliers are required to perform to conform to the standard
- Design details; how to design a repair
- Installation guidance; what are the critical issues, e.g. surface preparation and applicator training requirements
- Monitoring guidance; how to inspect the repair system

No other reference standard or guideline is required to complete the composite repair.

There are also two ASME composite repair standards:

- ASME PCC-2 Article 4.1: Non-metallic composite repair systems for pipelines and pipework: High risk applications
- ASME PCC-2 Article 4.2: Non-metallic composite repair systems for pipelines and pipework: Low risk applications

The scope of these ASME PCC-2 standards includes pipelines and pipework but not tanks and vessels. The content of the three composite repair standards mentioned is comparable and not contradictory. These standards cover pressure containment applications including pipelines, pipework and vessels also including risers. However, there is no current standard that covers structural strengthening of primary (or secondary) members. For this application of composite repairs, each application must be treated on its own merit and designed specifically for the intended application.

ALLOWABLE DEFECT TYPE

The types of defects that are covered by ISO/TS 24817 include:

- External corrosion, e.g. general wall loss, where the defect is or is not through wall. In this case the application of a repair system will usually arrest further deterioration - Defect type A
- External damage such as dents, gouges and fretting e.g. at supports - Defect type A
- Internal corrosion or erosion, e.g. general wall loss or pitting corrosion, where the defect is or is not through wall. In this case corrosion and/or erosion may continue after application of a repair system and therefore the design of the repair system should take this into account, i.e. the defect may continue to grow and become through wall (if not already through wall) Defect type B

In the above description of the types of defects, growth can be in either, or both, the axial and hoop direction.

Crack like defects are not covered by ISO/TS 24817, although, if it can be demonstrated in the defect assessment procedure that the crack will not grow, a composite repair can be applied to strengthen the defect affected region. Also, composite repairs may be applied to surface breaking cracks where the intention is to prevent leakage. This application will in most cases be short term as the repair will not prevent either further crack formation or crack growth. In general, the repair of crack like defects using composites will not stop crack growth. However, composite repairs may be used as a short-term solution until an alternative repair or replacement option is available.

Leaking defects cannot be directly repaired. The leak needs to be stopped before the appropriate surface preparation procedure for the repair system can be applied.

ISO/TS 24817 does not define what is an acceptable defect to repair, but assumes that a decision has been made to repair a given defect, under the relevant code, using a composite repair. The decision of what constitutes an acceptable defect for repair is beyond the remit of ISO/TS 24817.

APPLICATION

ISO/TS 24817 defines the range of potential applications in terms of Classes. Simply, these Classes can be considered as a simplified risk assessment grouping in terms of application.
Table 1 lists the definition of Class with example applications. Class 1 refers to low risk applications, with higher Class numbers referring to higher risk applications.

The class of repair (from Table 1) will determine the detail of the design method to be carried out, design margin or safety factor, together with the requirements for supporting documentation.

In general, all substrates (i.e. pipe or piping materials) can be repaired. To qualify the repair system for each substrate material in question, the appropriate qualification tests (as defined in ISO/TS 24817, Section 8.2) must be performed.

In general, composite repair systems can be applied to the following applications:

- Above ground and buried pipelines
- Piping • Tanks and vessels
- Splash zones
- Jetties

Table 1: Repair Classes

Repair Class	Typical Service	Pressure	Temperature
Class 1	Low specification duties, e.g. static head, drains cooling medium, sea (service) water, non-leaking utility hydrocarbons	< 10 bar g	-20 to 40C
Class 2	Fire water/deluge systems	< 20 bar g	-20 to 100C
Class 3	Produced water and hydrocarbons, flammable fluids, gas systems. Class 3 also covers operating conditions more onerous than described.	Qualified upper limit	-50C to qualified upper limit

Repair systems can be applied to the following substrates:
- Carbon steel
- Cast iron
- 316 stainless steel
- Duplex
- Super Duplex
- 6 Moly
- Titanium
- Cunifer

• FRP - Fibre Reinforced Plastic (e.g. glass reinforced epoxy, vinyl ester or polyester) pipe. In general composite repairs can be applied to FRP where the P is a thermo-setting resin but cannot be applied to thermoplastic systems, e.g. Polyethylene or Polypropylene.

Simple decision guidance rules are presented in Appendix 1 to help decide if a composite repair is feasible for the intended application. These rules should be used as a guide only. There will be situations where a generic guide such as this is not appropriate but the aim is to provide some initial guidance as to whether a repair using a composite solution is practical.

5 CHEMICAL COMPATIBILITY

The following service fluids are considered acceptable for the application of composite repair systems:

- water, sea-water
- produced hydrocarbons, both liquids, gas and gas condensate including alkanes and cyclo-alkanes
- utility fluids including diesel, air

To assess the chemical compatibility of a repair system to either the internal or external environment the following approach is adopted by ISO/TS 24817; qualification tests (Section 8.2) demonstrate that the repair system is compatible with aqueous environments at the qualification test temperature and aqueous environments are relatively aggressive towards thermoset resins. In general, thermoset resins (e.g. epoxies, vinyl esters) are compatible with a wide range of environments but in environments which are strongly acidic (pH<3.5), strongly alkaline (pH>11) or contain a strong, polar solvent (e.g. methanol, toluene) in concentration greater than 25%, then guidance on compatibility should be confirmed with the repair supplier. Resistance to UV degradation and weathering is not a concern for repair systems as all commercial resin systems have UV stabilisers added.

6 APPLICATION ENVELOPE

The application envelope of a specific composite repair system can be defined in terms of an upper pressure and temperature limit and also a lower temperature limit.

UPPER PRESSURE LIMIT OF A QUALIFIED REPAIR SYSTEM

The upper pressure of a repair system is a function of the type of defect under consideration and the thickness of the repair laminate. A specific pressure cannot be defined until these application parameters are given.

UPPER TEMPERATURE LIMIT OF A QUALIFIED REPAIR SYSTEM

The upper service temperature of a repair system is a function of the glass transition temperature (Tg), or heat distortion temperature (HDT) of the resin system. The following table summarises the maximum temperature limits.

Table 2: Upper Service Temperature Limit

Temperature measurement	Defect type B	Defect type A
Tg	TG-30C	Tg-20C
HDT	HDT-20C	HD-15C

LOWER TEMPERATURE LIMIT OF A QUALIFIED REPAIR SYSTEM

There is no material limitation on the lower service temperature limit of a composite repair. From ambient temperatures down to -45C both the modulus and strength remain approximately constant. However, the thermal expansion (contraction) mismatch between the composite repair and the substrate places a mechanical limit on the lower temperature of application. Typically, this value of lower temperature performance ranges from -50 to -100C, depending on the repair material and substrate. At temperatures lower than -45C a detailed design calculation must be performed to demonstrate that the strains developed within the repair laminate (both axial and circumferential) through thermal mismatch are less than the design allowable.

7 QUALIFICATION DATA

The purpose of qualification of a repair system is to demonstrate that the repair system is appropriate for the intended application and also to provide the relevant mechanical data for the design of the repair. The qualification data for the repair system should be contained within the technical specification of the repair system supplier. This specification should not only contain the data but should also state the test method used to obtain that data.
The required qualification test data as defined by ISO/TS 24817 is:

Table 3: Repair system qualification test requirements

	Material Property	Test Methode
Mechanical properties	Young's model	ISO 527 or ASTM D3039
	Poisson's ratio	ISO 527 or ASTM D3039
	Shear modules	ASTM D5379
	Thermal expansion coefficient	ISO 11359 or ASTM D696
	Glass transition temperature of resin or heat distortion temperature of resin	ISO 11357-2 or ISO 75, ASTM D6604, ASTM E1640, ASTM E831, ASTM E2092
	Barcol or Shore hardness	BS EN 59 or ISO 868 or ASTM D2583
Adhesion strength	Lap shear	BS EN 1465 or ASTM D3165
Operational performance data	Long-term strength	ISO 24817 Annex E, ASME PCC-2 Annex
Defect type A only	Short-term pipe spool survival test	ISO 24817 Annex C, ASME PCC-2 Annex
Defect type A and B	Energy release rate test	ISO 24817 Annex D, ASME PCC-2 Annex 4
	Impact test	ISO 24817 Annex F, ASME PCC-2 Annex 6

Appendix 2 presents a summary diagram on repair supplier selection for the range of defect types and service conditions considered in ISO/TS 24817.

8 DESIGN

The design process of a composite repair system answers the following questions;
• Is the composite repair system strong enough to carry the applied loads in both axial and hoop directions? (termed the strength calculation)
• Will the repair laminate remain bonded to the surface, for through wall defects (defect type B) only, for the design life of the repair? (termed the strength of bond calculation)
• Is the extent of the repair laminate sufficient to ensure load transfer between repair and substrate? (termed the axial extent calculation)

All these questions require answering for any repair application. The outputs of the design calculation for the repair system are;
• Thickness of the repair laminate (expressed in terms of the number of wraps)
• Total axial repair length (it is assumed the repair covers the full circumference of the substrate)

The repair design should follow ISO/TS 24817. The input for the design calculation requires a definition of all possible loads, both short-term and long-term that could act on the repair. These loads include hoop, axial, bending, torsion and shear. The design rules convert these applied loads into equivalent axial and hoop applied loads and it is these two equivalent loads that are used in the repair laminate strength calculation.

8.1 REPAIR LIFETIME
The lifetime of a composite repair system is often termed permanent or temporary. These two definitions have been removed due to the vagueness of their definition. Instead repair lifetime (up to 20 years in some cases) should be specified as part of the design input information that is provided to the repair supplier. Within ISO/TS 24817 a minimum default lifetime of 2 years is specified.

8.2 DESIGN TEMPERATURE
The influence of design temperature is accounted for in the design calculation. Repair suppliers perform their qualification tests at a set test temperature. If the design temperature is greater than the qualification test temperature, but less than the maximum temperature limits (as defined in Table 2 above), then temperature de-rating factors are provided within ISO/TS 24817.

8.3 AXIAL EXTENT OF REPAIR
The overlap length (axial extent) of the repair is defined as the axial length of the repair from the edge of the defect to the edge of the repair. The minimum required overlap length is a function of the defect type. Formulas are provided in ISO/TS 24817 for determining this axial length. It is always recommended to taper the repair especially when axial loads are present. The (axial) taper length is additional to the overlap length and should be at least 5 times the repair thickness.

8.4 PIPING COMPONENTS, TANKS AND VESSELS
The previous discussion has implicitly assumed that the substrate is a straight pipe section. The repair design procedure for other components (e.g. bends, tees, nozzles etc.) is a comparative approach based on an equivalent straight pipe component. This procedure is comparable to other piping system design procedures. The design procedure is first to calculate the thickness of the repair for an equivalent straight pipe section followed by a further calculation of a multiplicative factor, called the repair thickness increase factor, which accounts for the stress intensification due to the geometry of the component. The design repair thickness for the component is given by the product of the repair thickness increase factor times the repair thickness for the equivalent straight pipe section. ISO/TS 24817 (Section 5) presents repair thickness increase factors for each component listed.

8.5 REPAIR DATA DESIGN SHEET
Appendix 3 presents a data sheet which the Owner should complete to enable the repair supplier to perform the design of the repair. It is important that as much information as possible is provided to the repair supplier to enable an accurate repair design to be performed.

9 INSTALLATION

The application of a composite repair system requires either;
• the combination of a fibrous reinforcement and a thermosetting polymer matrix that is subsequently subject to a chemical curing process or
• the adhesion of a pre-engineered roll

This implies that the load carrying material is formed or cured as or immediately after the repair is applied. The final properties of the repair are significantly influenced by the method of application, the details of the lay-up, the form of reinforcement used and the curing of the resin or adhesive. These points emphasise the need for installation procedures to be fully controlled, to ensure that the repair achieved on site is the same from a technical point of view as that previously qualified by the repair system supplier. Appendix 4 contains an installation check list which contains guidance on how to ensure that a repair system has been correctly installed.

9.1 INSTALLER QUALIFICATION
Personnel involved in the installation of composite repairs should be appropriately trained and be qualified in the repair method to be undertaken. The minimum training and knowledge requirements of both installers and supervisors are detailed in ISO/TS 24817. This should include the handling of composite materials, surface preparation, lay-up techniques, quality control procedures, and health and safety issues. It is important that the training given provides sufficient technical background to allow personnel to obtain a good understanding as to why key operations such as surface preparation, material handling and lay-up technique are so important. It should also be noted that using trained

installers and supervisors is an essential element of a successful repair. Training in one repair option does not necessarily qualify personnel for alternative methods.
Installers should be the subject of a continuing review of competency with a log book kept of experience in the application of repairs. ISO/TS 24817 defines a minimum of 10 composite repairs in one year as a sufficient number of repair applications to demonstrate continued competency. This is important as the levels of competence and experience achieved by an individual installer should also be considered in the context of repair activities. For example, working in confined spaces or applying material around complicated geometries can pose additional difficulties that should be taken in to account. Supervisors should be trained in the relevant technique and ideally should have had a period during which they were engaged in the application of repairs. Supervisors should also be the subject of a continuing review of competency, as defined in ISO/TS 24817.

9.2 INSTALLATION GUIDANCE

The repair system supplier should provide full installation instructions. The guidance given in the following sections is intended to complement that given by the repair system supplier and to emphasise the key operations necessary for a successful repair.
Full instructions for each repair system application should be included in the repair method statement.

Surface Preparation

Surface preparation is the single most important operation in the achievement of a successful repair. The surface preparation should extend over the whole surface onto which the composite repair is to be applied, i.e. the total axial extent of the repair.

Laminate Lay-up

The details of the lay-up procedure vary according to the repair system to be used and these should be fully specified by the repair system supplier.

Cure

The cure of a repair laminate is strongly influenced by temperature and the correct mixing of resin constituents prior to application. It is important that the prevailing temperature conditions are considered when resin catalyst levels are being assessed. On no account, however, should the limits set by repair system supplier be exceeded without recourse to further information. It should be noted that for curing in extreme ambient conditions there may be special resin formulations that may be required.

Key Hold Points

The key hold points to be observed during repair installation are given below:

Table 4: Key Hold Points

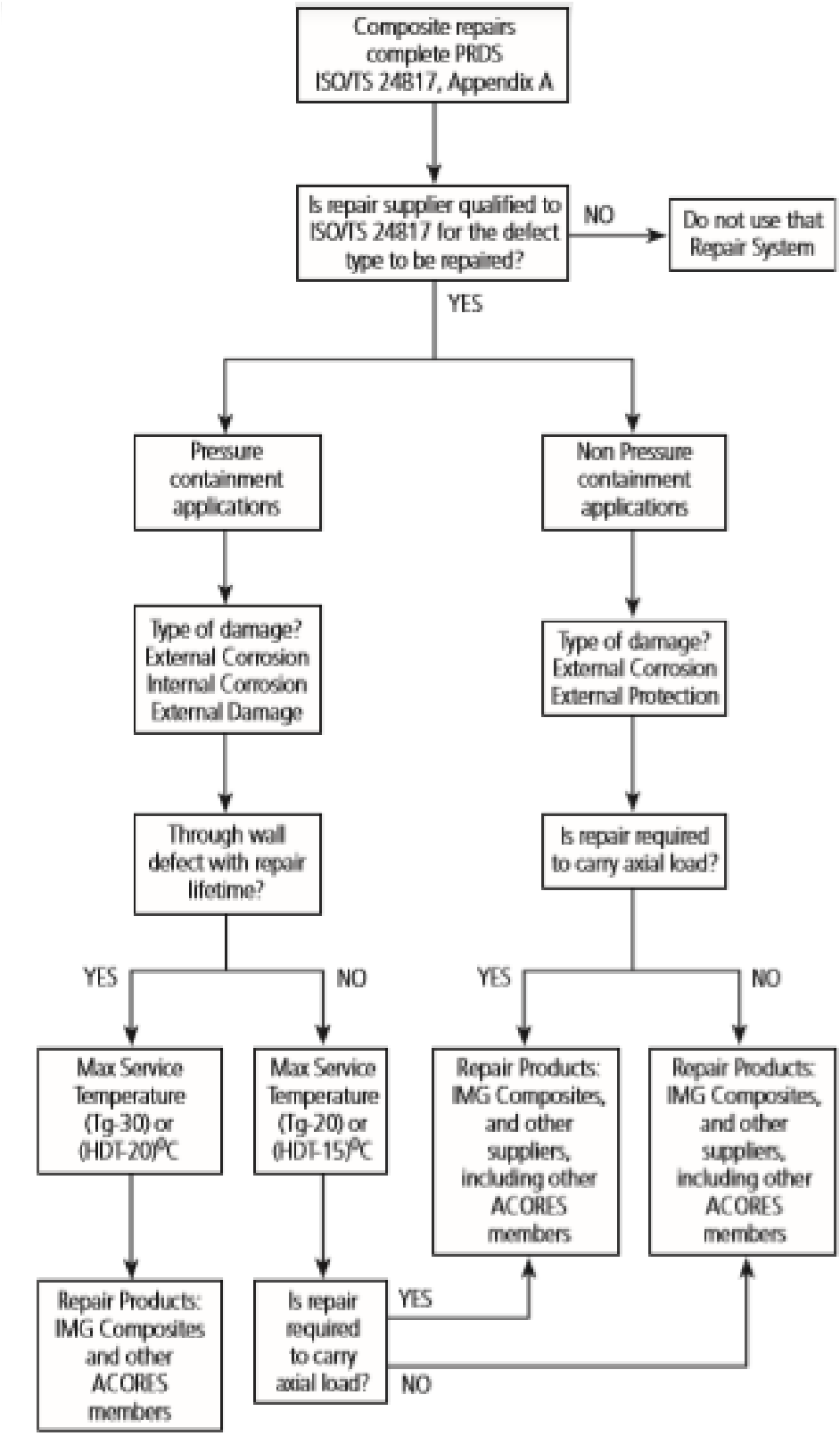
Hold Point	Checked by
Methode statement	Installer
Risk assessment	Supervisor
Materials preparation inspection, mechanical test- reinforcement, resin	Installer
Surface preparation-	Supervisor
Filler profile	Installer
Stage check on reinforcement	Installer
Test on repair laminate- cure, thickness, dimensions, external inspection	Supervisor
(Hydro) Pressure Test (if required by Technical Authority)	Inspection Authority

Appendix 1 REPAIR DECISION GUIDANCE

Defect Type	Pressure Diameter (units bar.mm)	Maximum Pressure (bar)	Maximum Temper-ature (°C)	Enviroment (in contact with repair)	Comment
External	<20,000	200	250	Water, air, soil with 4<pH<11	Generally lifetime of repair can be up to 20 years
Internal and/or through wall	<15,000	100	150	Hydrocarbon, gas, water with 4<pH<11	Repair will not halt degradation process so an indication on rate is required for the intended lifetime of the repair. The repair must be designed with the defect size estimated at end of life.
Structural strength-ening	N/A	Max. strain in composite 0.0025	250	Water, air, soil with 4<pH<11	

The above limits should be seen solely as a guide. Not all repair systems supplied can meet these limits, so caution is required in interpretation. For higher temperatures, greater than 400C, care should be taken that the environment does not limit the application and lifetime of the repair. If in doubt about the compatibility of the environment with the repair laminate, contact the repair supplier.

Appendix 2 REPAIR SUPPLIER SELECTION GUIDE



Appendix 3 REPAIR DESIGN DATA SHEET

This Appendix provides an example of a design data sheet. This data sheet should form the basis of the scope of work provided by the client to the repair system supplier and be used in the preparation of the design of the repair. One sheet should be completed for each repair. In practice it may not be possible to define all the input data sheet values, e.g. all the loads acting on a piping system. In this case it is recommended to first discuss with the repair system supplier about any specific parameter and its relevance; a compromise should be reached on the actual value of this parameter to be used in the design. The boxes marked in red contain information without which it is impossible to even commence the Design Process.

Document Number:			
Project Title:			
Date of Issue:		Issue No.:	

PIPE REPAIR DATA SHEET			
Section 1.0a Onshore Contact Details		Section 1.0b Please return to	
Contact Name:		Contact Name:	
Company Name:		Company Name:	
Address:		Address:	
Post Code/ZIP:		Post Code/ZIP:	
Country:		Country:	
Telephone:		Telephone:	
Fax:		Fax:	
Mobile:		Mobile:	
email:		email:	
Section 1.0c Asset Contact Details			
Contact Name:		Telephone:	
Designation:		email:	
Section 2.0 Pipe Details			
Installation Name:		Location:	
Quantity:		Pipe Identification:	
Pipe Reference:		Pipe Specification:	
Material Grade:		External Diameter (ins):	
Wall Thickness (mm):		Medium:	
Operating Temperature (°C):		Existing Pipe Coating:	
Section 3.0 Assessment of Repair Classification			
Repair Class:		Required Repair Lifetime:	
Other Repair Data:			

Section 4.0 Pipe Loading:				
Please note any original design calculations or piping isometrics should be appended to this sheet and loads should be defined as "sustained" or "occasional" in the Comments box.				
	Operating	Design	Test	Comments
Pressure Rating (bar g):				
Axial Load:				
Bending Moment:				
Shear Load:				
Torsion:				
Other loads:				

Section 5.0 Details of Defect Area:
Drawings of the pipe system and inspection reports, where available, should be appended to this data sheet. Please indicate any access restrictions and proximity to other equipment. Where available, digital photographs of the defect area(s) are to be appended.

Section 6.0 Repair Specification:					
Type of Defect:			Nature of Defect:		
Current Size, Area:	(mm²)		Current Size, Depth:	(mm)	
Projected Size, Area:	(mm²)		Projected Size, Depth:	(mm)	
Cause:			Effect:		
Perforated?			MAWP (API 579)		
Section 7.0 Anticipated Conditions During Implementation of Repair:					
Pipe Temperature:	min °C		Pipe Temperature:	max °C	
Ambient Temperature:	min °C		Ambient Temperature:	max °C	
Humidity:			External Environment:		
Constraints:					

Appendix 4 INSTALLATION CHECKLIST

INSTALLATION CHECKLIST

Hold Point	Comment
Method statement	This document should contain the details of the repair, statement the installation procedure, installer qualifications. It should also indicate required facilities on site, e.g. enclosures etc.
Materials preparation-reinforcement, resin	Check to ensure sufficient reinforcement and resin preparation available for the repair. Check that appropriate volumes of resin and resin hardener are available.
Surface preparation-inspection, mechanical test	Check that the surface preparation procedure has preparation - been performed according to the installation procedure. inspection, Procedure could include mechanical abrasion mechanical e.g. grit blasting and chemical cleaning. Ensure correct test sequence of cleaning and abrasion. Surface profile (mechanical) should be measured by profile pad.
Filler profile	Check that filler has been applied according to installation procedure and smoothed to the correct profile.
Reinforcement application	Check that the appropriate number of layers or wraps application have been applied. Check that the appropriate layer orientation is applied. Check that the correct axial extent of repair has been applied. Check that the taper geometry is applied.
Curing of repair	Check that the correct time for cure has elapsed before of repair re-starting the system through hardness measurement. If post curing is required, then check that the heating blanket is set to the correct temperature.
External inspection	Check that there are no visible defects.